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VALIDATION OF AIRCRAFT NOISE EXPOSURE PREDICTION PROCEDURE.(U)

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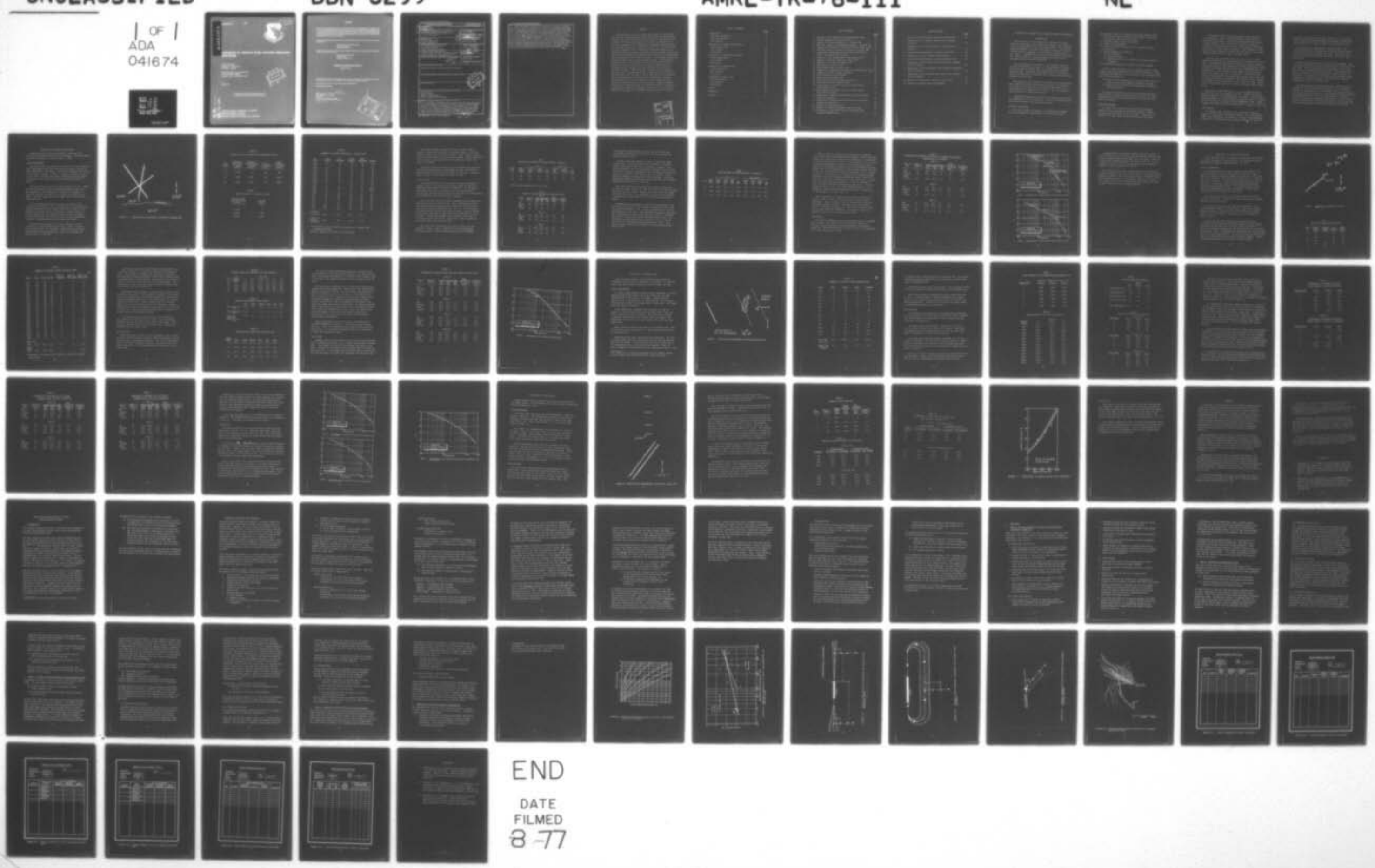

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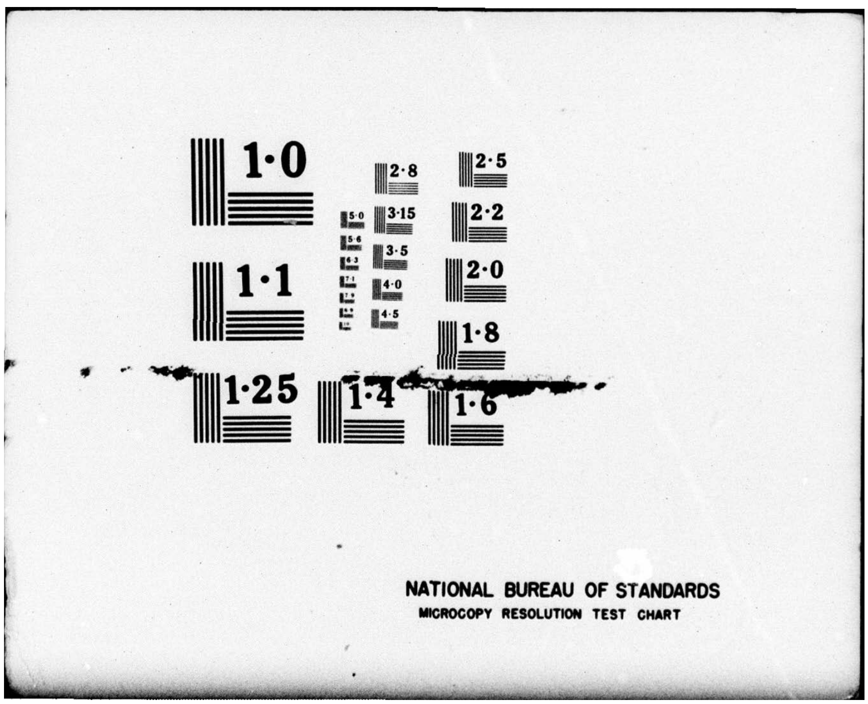
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VALIDATION OF AIRCRAFT NOISE EXPOSURE PREDICTION PROCEDURE

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APRIL 1977

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FOR THE COMMANDER

HENNING E. VON GIERKE
Director
Biodynamics and Bionics Division
Aerospace Medical Research Laboratory

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The NOISEMAP predictive procedure is used to describe the noise environment around airbases and thereby aid airbase planners to prevent community encroachment limiting the effectiveness of the installation. This report delineates the results of measurements made over one to three week periods at four Air Force airbases to acquire the data needed to validate and/or modify the noise predictive algorithms in NOISEMAP for takeoff, landing, traffic pattern, and ground runup operations. The findings showed:

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(a) NOISEMAP overestimates takeoff noise exposure by 0 to 1 dB; (b) NOISEMAP overestimates landing noise exposure by 0 to 1 dB; (c) NOISEMAP underestimates traffic pattern noise exposure by 0 to 4 dB due to dispersion about the flight path; (d) NOISEMAP predicts ground runup noise levels by ± 2 dB for distances out to 5000 feet from the runup pad, but underestimates the noise levels by 1 to 5 dB for longer distances (out to 9000 feet from the pad) due to local meteorological effects and uncertainties in the excess sound attenuation (ESA) model used; and (e) NOISEMAP overestimates noise exposure to the side of aircraft flight paths by up to 4 dB due to effects of fuselage shielding for multi-engine aircraft and uncertainties in the air-to-ground versus ground-to-ground propagation transition model used. In general, the algorithms currently used in NOISEMAP provided predictions that agreed well with measured data. It was found that obtaining accurate data on aircraft operational procedures (engine power settings, airspeeds, and flight paths) was essential.

PREFACE

This report is one of a series describing the contractual and in-house research program undertaken by the Aerospace Medical Research Laboratory under Project/Task 723104, "Measurement and Prediction of Noise Environments of Air Force Operations," to develop a procedure for predicting the community noise resulting from aircraft operations. Technical monitor for this effort was Mr. Jerry Speakman of the Biodynamics Environment Branch, Biodynamics & Bionics Division, Aerospace Medical Research Laboratory. This effort was partially funded by the Air Force Civil Engineering Center, Tyndall Air Force Base, Florida. Other reports previously published under this research program include: AMRL-TR-73-105, "Community Noise Exposure Resulting from Aircraft Operations: Application Guide for Predictive Procedure"; AMRL-TR-73-106, "Community Noise Exposure Resulting From Aircraft Operations: Technical Review"; AMRL-TR-73-107, "Community Noise Exposure Resulting from Aircraft Operations: Acquisition and Analysis of Aircraft Noise and Performance Data"; AMRL-TR-73-108, "Community Noise Exposure Resulting from Aircraft Operations: Computer Program Operator's Manual"; AMRL-TR-73-109, "Community Noise Exposure Resulting from Aircraft Operations: Computer Program Description"; AMRL-TR-73-115, "Sensitivity Studies of Community-Aircraft Noise Exposure (NOISEMAP) Prediction Procedure"; and AMRL-TR-73-108 Appendix, "NOISEMAP Program Operator's Manual".

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

VALIDATION OF AIRCRAFT NOISE EXPOSURE PREDICTION PROCEDURE

INTRODUCTION

The objective of this study was to validate the noise exposure algorithms in the predictive computer model currently used at the Air Force Civil Engineering Center. The computer program, NOISEMAP, calculates and draws contours of equal NEF or DNL values to represent the noise from operations at an air base.[1,2] NOISEMAP was developed by Bolt Beranek and Newman Inc. (BBN) as part of research programs sponsored by the Aerospace Medical Research Laboratory.

Field measurements were made at four different bases to validate four different situations. Measurements of takeoff noise were made at England AFB. Landing noise was measured at Travis AFB. Noise from the downwind leg of the practice pattern was measured at Barksdale AFB. Engine runup noise was measured at Nellis AFB.

The purpose of the study was to determine why field measurements agree or disagree with predicted values. The scope of this project was to perform a generalized validation of the algorithms in the computer model, rather than a validation of noise contours at a specific air base.

A generalized discussion of the work is given in the following subsections of the introduction. Detailed information for each base is given in the following sections.

TECHNICAL BACKGROUND

There are a number of aspects of the prediction program which were subject to check during the validation study:

(1) Aircraft noise vs. distance curves (per aircraft type)
(2) Takeoff and landing profiles for aircraft (including appropriate engine power settings)
(3) Aircraft flight tracks over ground
(4) Flight path dispersion
(5) Volume of aircraft operations per aircraft type per time period
(6) Sound propagation assumptions
   (a) Air-to-ground
   (b) Ground-to-ground
   (c) Transitions from air-to-ground to ground-to-ground propagation
(7) Atmospheric absorption (seasonal and daily changes)

The test plan developed for this project listed a large number of potential situations that could be validated. This is included as Appendix A of this report. The situations used were selected because of:

(a) Their relative importance to air base noise environments and air base/community annoyance concerns,
(b) Their relative potential contributions to improved prediction models.

The selected situations omitted some cases which are of great physical complexity and technical interest, but which generally are not major contributors to the total air base noise environment.

FIELD MEASUREMENTS

Air bases were selected that provided the necessary operations with a minimum of interfering events. Formal criteria were set forth in the test plan. These will be enumerated in more detail as each situation is discussed.

The procedure for collecting noise data was similar for all situations. Three or four measurement locations were selected at each base. Continuous noise monitors were placed at each location. The monitors are designed to digitally record the "A" weighted noise level every one-half second when the noise is above a preset threshold. Data recorded in this fashion can be analyzed to obtain data for single events (SEL), hourly averages (HNL), or daily averages (DNL).

Portable tape recorders were used to collect a limited amount of analog data at the bases with the exception of Nellis AFB. The infrequent and random scheduling of engine runups at Nellis AFB did not allow scheduling of analog recordings. Radar tracings of aircraft movements were made at Barksdale AFB and England AFB. An air traffic control radar scope was used to track the aircraft through its operation. A piece of clear acetate was placed over the screen and a grease pencil was used to trace the aircraft's movement. The altitude of the aircraft is displayed on the screen and this was also recorded. Dispersion of the aircraft can be calculated based upon this information.

Data on the number and types of aircraft operations were recorded for each base except Nellis AFB. Operational data on engine runups was not recorded by base personnel at Nellis AFB. These data were used in the computer simulation model to calculate the predicted noise exposure at each measurement site. Meteorological data were obtained from the weather station at each base.

DATA ANALYSIS

The digital tapes recorded in the field were reduced by computer to obtain SEL, HNL and DNL values. The hourly values (HNLs) were selected as the measure to validate the algorithms. Correlation of individual events (SELs) between sites and the

operations logs would be extremely difficult. Use of daily values (DNLs) would have provided a much smaller sample size and prevented use of data recorded over only parts of days.

HNL values were transferred to computer cards. The associated operations information, including type and number of aircraft, was also placed on the card. HNL values were then calculated using NOISEMAP algorithms and actual operational data.

The measured and predicted HNLs were then compared. Only hours where both the measured and predicted data exceeded 45 dB were used. The HNL values were then averaged, on an energy basis, for the entire measurement period. The average values and the difference between measured and predicted values is presented. A comparison of the predicted and measured energy averages gives a good indication of how well the computer program will predict the correct DNL.

The mean arithmetic differences between individual hourly values were also calculated and displayed. The arithmetic average was calculated as an intermediate step in the calculation of the standard deviation. The standard deviation indicates the variability of the data. The deviations are typically caused by variations in operations procedures. Another factor is that some operations occurred very near to the hour and may have been measured for one hour and calculated for another.

VALIDATION OF TAKEOFF NOISE LEVELS

England Air Force Base in Alexandria, Louisiana, was selected for making takeoff noise measurements. The measurements were made from March 19, 1976 to April 7, 1976.

FIELD MEASUREMENTS

Typically during the spring, all takeoffs are from Runway 14. Three measurement sites were selected to provide a variety of slant distances to the runway. These sites, numbered 21, 22 and 23 are shown in Figure 1. Table 1 shows the distance to each of the sites. Altitude information recorded during the radar tracing was used to generate the altitude profile shown in Table 2.

The main aircraft located at England AFB is the A-7. Almost 70% of all takeoffs during the measurement period were A-7s. The remainder of the operations is made up of a variety of transient one-and two-engine jet aircraft, and propeller aircraft. The most common jets other than the A-7s were T-33s, T-37s and T-38s.

The A-7s frequently depart in groups of three or four aircraft usually about 10 to 20 seconds apart. During patterns, the aircraft pass over the runway threshold at about 50 feet before they increase power to go around. Radar tracings of takeoffs showed that the aircraft typically make a straight out procedure until they were well over the last measurement location. Variations from this procedure were small.

Operations were logged by Air Force personnel for the period that noise measurements were made. Table 3 summarizes the operations that were recorded. Approximately 55% of the takeoffs were straight departures, while the remaining 45% were portions of a pattern.

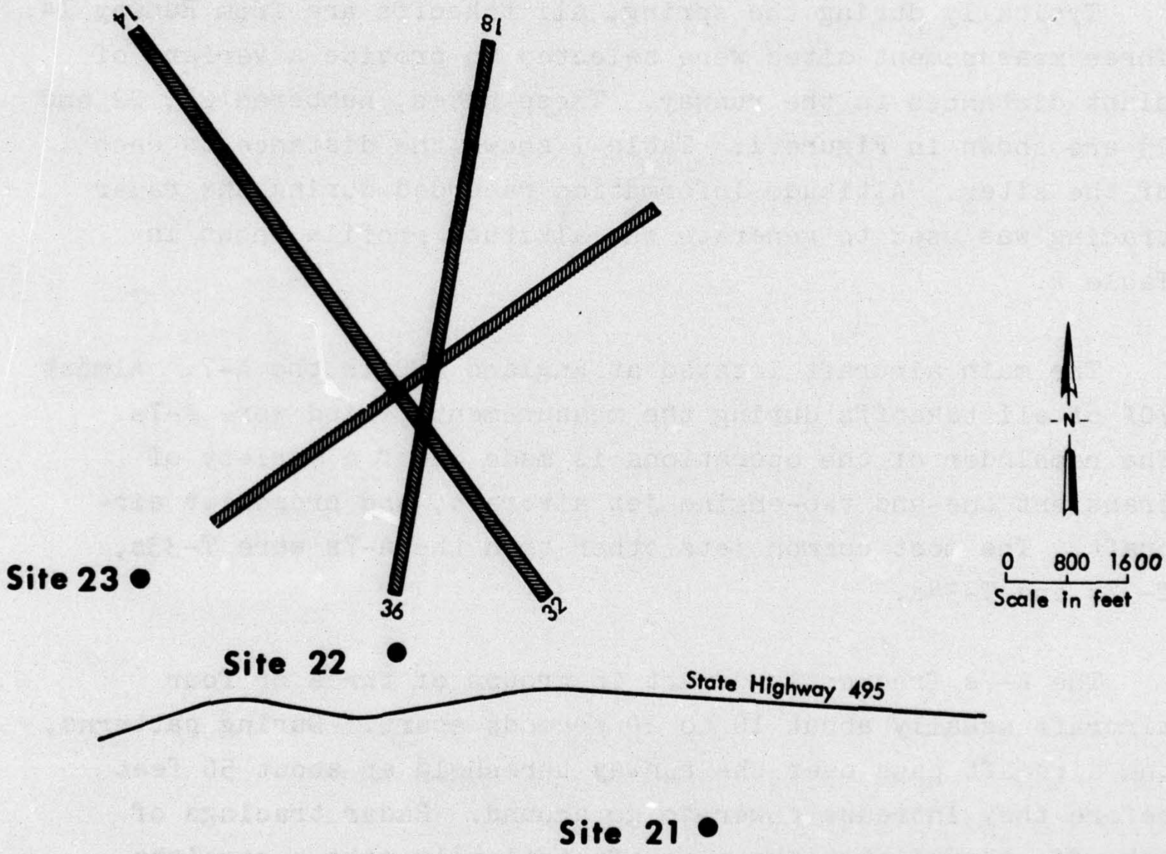

FIGURE 1. TAKEOFF NOISE MEASUREMENT LOCATIONS, ENGLAND AFB

TABLE 1

Distance to the Takeoff Noise Measurement Sites

Site Number	Distance From Start of Runway (Feet)	Distance Perpendicular to Runway (Feet)	Altitude of Aircraft (Feet)	Slant Distance to Aircraft (Feet)
21	12,800	70	539	543
22	8,500	2,050	275	2,068
23	5,800	4,075	110	4,076

TABLE 2

Typical Departure Altitude Profile

Distance from Start of Runway (Feet)	Altitude (Feet)
0	0
4,000	0
17,060	800
29,220	1,700

TABLE 3

SUMMARY OF AIRCRAFT OPERATIONS - ENGLAND AFB*

Date	A-7 Takeoff	A-7 Landings	Other Takeoff	Other Landings	Runway
3/19	37	40	39	37	14
3/20	2	5	12	8	14
3/21	12	17	5	2	32
3/22	68	76	31	31	14
3/23	84	90	42	43	14
3/24	66	69	7	13	14
3/25	20	20	17	11	14
3/26	85	81	11	11	14
3/27	9	7	8	7	32
3/28	9	13	24	23	32
3/29	55	55	18	19	32/14
3/30	0	0	2	2	32
3/31	95	94	43	38	32
4/1	89	106	38	45	32
4/2	84	78	33	51	14
4/3	0	2	12	12	14
4/4	12	10	21	19	14
4/5	104	121	19	16	14
4/6	125	138	35	31	14
Avg.Oper. 3/19-4/16	50.3	53.8	21.9	22.1	
Annual ** Average Operations	45.2	45.7	7.9	7.9	

* An aircraft flying a pattern was counted as 1 takeoff and 1 landing per cycle.

**Source: England AFB, Phase II AICUZ Report

The annual average operations are also shown in Table 3. During the measurement period, the average number of A-7s was slightly higher than the annual average. Other aircraft operations were also higher than the annual average. Daily variations are relatively large going from zero operations to more than twice the average.

Because of weather conditions, the operations were reversed for several days during the measurement period. The weather also prevented servicing the equipment on occasion. A tornado warning caused all operations to cease one day.

DATA ANALYSIS

The data recorded in the field were reduced and placed on computer cards. The runway used was also noted so that only departures from Runway 14 would be considered. The operations were broken down into two groups, A-7s and other aircraft. For purposes of this analysis the T-37 was used as the representative aircraft for the other aircraft category.

SEL noise data from the standard NOISEFILE data package were obtained for the A-7 and the T-37. The configuration is such that air-to-ground propagation was assumed for Sites 21 and 22 and ground-to-ground propagation for Site 23. It was assumed that all aircraft whether departing or flying a pattern takeoff at military power and no other corrections were made for power settings. It was also assumed that a maximum climb speed of 350 knots would be reached at 13,000 feet. Table 4 shows the SEL noise levels used for each site.

HNL values were calculated for each hour that noise was measured. Table 5 shows a comparison of the measured and predicted values. Using standard assumptions in NOISEMAP,

TABLE 4

PREDICTED SEL NOISE LEVELS FOR STANDARD DEPARTURES - ENGLAND AFB

		A-7			Other (T-37)		
Site Number	Slant Distance (Feet)	Uncorrected SEL (dB)	Speed Correction (dB)	SEL (dB)	Uncorrected SEL (dB)	Speed Correction (dB)	SEL (dB)
21	543	115.3	- .7	114.6	101.8	- .7	101.1
22	2068	105.5	+1.1	106.6	92.5	+1.1	93.6
23*	4076	93.6	+2.2	95.8	80.2	+2.2	82.4

* Ground to ground propagation used at this location.

TABLE 5

COMPARISON OF MEASURED AND PREDICTED TAKEOFF NOISE LEVELS

Time of Day	Number of Samples	Energy Average HNL Pred. (dB)	Energy Average HNL Meas. (dB)	Energy Average HNL Diff. (dB)	Mean Arithmetic Difference (dB)	Standard Deviation (dB)
SITE 21						
Day	92	87.4	83.6	3.8	2.5	6.4
Evening	15	85.6	82.4	3.2	6.8	8.3
Night	0	-	-	-	-	-
24 Hour	107	87.2	83.5	3.7	3.1	6.8
SITE 22						
Day	52	79.7	78.1	1.6	3.2	8.5
Evening	11	78.3	73.6	4.7	3.9	6.3
Night	0	-	-	-	-	-
24 Hour	63	79.5	77.6	1.9	3.3	8.2
SITE 23						
Day	59	69.8	66.2	3.7	1.4	6.9
Evening	1	60.2	66.6	-6.4	-6.4	-
Night	0	-	-	-	-	-
24 Hour	60	69.8	66.2	3.6	1.2	6.9

the algorithms overestimate the noise by two to four dB, independent of whether the site is in the air-to-ground or ground-to-ground regime.

Several items were checked to try to account for these differences. It was discovered that aircraft in a pattern operate differently from those performing a takeoff. The pattern flights cross over the runway threshold at an altitude of 50 feet. Power is increased to full military power but then reduced to 92% RPM as they proceed over the runway. Their speed is slightly increased as is their altitude. During the measurement period, approximately 55% of takeoffs were straight departures and 45% were in a pattern.

The slant distances calculated for aircraft flying in a pattern are shown in Table 6. The corrections for power settings and speed are also shown. Finally, the noise levels for these operations are given. The additional altitude of the aircraft is sufficient to barely place Site 23 into the air-to-ground regime.

Standard day meteorological conditions were assumed in the predicted noise levels. The standard temperature is 59° F and the relative humidity is 70%. Actual temperature and humidity were measured at the base. The atmospheric absorption associated with the measured meteorological data was scanned to determine what effect it would have on the predicted noise levels. At 1000 Hertz, the attenuation would decrease 0.0 to 0.6 dB per 1000 feet thus increasing the predicted noise levels. This would slightly increase the difference between predicted and measured data.

TABLE 6
SEL NOISE LEVELS FOR PATTERN OPERATION - ENGLAND AFB

		A-7				Other (T-37)			
Site	Slant Dist. (feet)	Uncorr. SEL (dB)	Power Corr. (dB)	Speed Corr. (dB)	SEL (dB)	Uncorr. SEL (dB)	Power Corr. (dB)	Speed Corr. (dB)	SEL (dB)
21	1302	109.2	-6.4	+ .1	102.9	96.0	-1.6	+ .1	94.5
22	2224	104.8	-5.8	+ .9	99.9	91.9	-1.5	+ .9	91.3
23	4117	98.9	-4.0	+1.5	96.4	86.4	-1.0	+1.5	86.9

Table 7 shows the comparison of predicted and measured noise levels when the patterns are considered. Because aircraft flying in a pattern are quieter than a departure, the agreement is much better at Sites 21 and 22. The agreement at Site 23 did not change significantly because the increased noise levels caused by the aircraft shifting to the air-to-ground regime was about equal to the decrease due to the aircraft flying a pattern. At Site 23, the elevation angle of the aircraft is 8.2° during a pattern. In NOISEMAP, the transition from ground-to-ground propagation and air-to-ground propagation occurs between 4.3° and 7.2°. Since the configuration is such that Site 23 is very near to ground-to-ground propagation, it was of interest to rerun the case using ground-to-ground noise values. For this assumption which is not the normal NOISEMAP procedure, the difference between predicted and measured HNLs is reduced to 2.1 dB instead of 3.9 dB at Site 23.

The analog data are compared with standard noise data in Figures 2 and 3. Figure 2 plots the data recorded during departures. Figure 3 shows the data for aircraft flying over the runway during a pattern. The speed corrections (delta offsets) calculated in Table 4 for the three sites were added to the noise data from NOISEFILE. The measured values are typically lower than the standard noise data.

CONCLUSIONS

The takeoff assumptions used in preparing inputs to NOISEMAP were studied. One method is to model aircraft flying in a practice pattern and doing a missed approach as performing a departure. This overestimated the noise levels at the departure end of the runway by 2 to 4 dB.

TABLE 7

COMPARISON OF MEASURED AND PREDICTED TAKEOFF NOISE LEVELS

(ACCOUNTING FOR PATTERNS)

Time of Day	Number of Samples	Energy Average HNL Pred. (dB)	Energy Average HNL Meas. (dB)	Energy Average HNL Diff. (dB)	Mean Arithmetic Difference (dB)	Standard Deviation (dB)
SITE 21						
Day	92	85.0	83.6	1.4	.3	6.3
Evening	15	83.2	82.4	.8	4.5	8.3
Night	0	-	-	-	-	-
24 Hour	107	84.8	83.5	1.4	.9	6.7
SITE 22						
Day	52	77.8	78.1	-.3	1.6	8.3
Evening	11	76.4	73.6	2.8	2.2	6.0
Night	0	-	-	-	-	-
24 Hour	63	77.6	77.6	0	1.7	7.9
SITE 23						
Day	59	70.2	66.2	4.0	2.3	6.2
Evening	1	60.5	66.6	-6.1	-6.1	0
Night	0	-	-	-	-	-
24 Hour	60	70.1	66.2	3.9	2.1	6.2

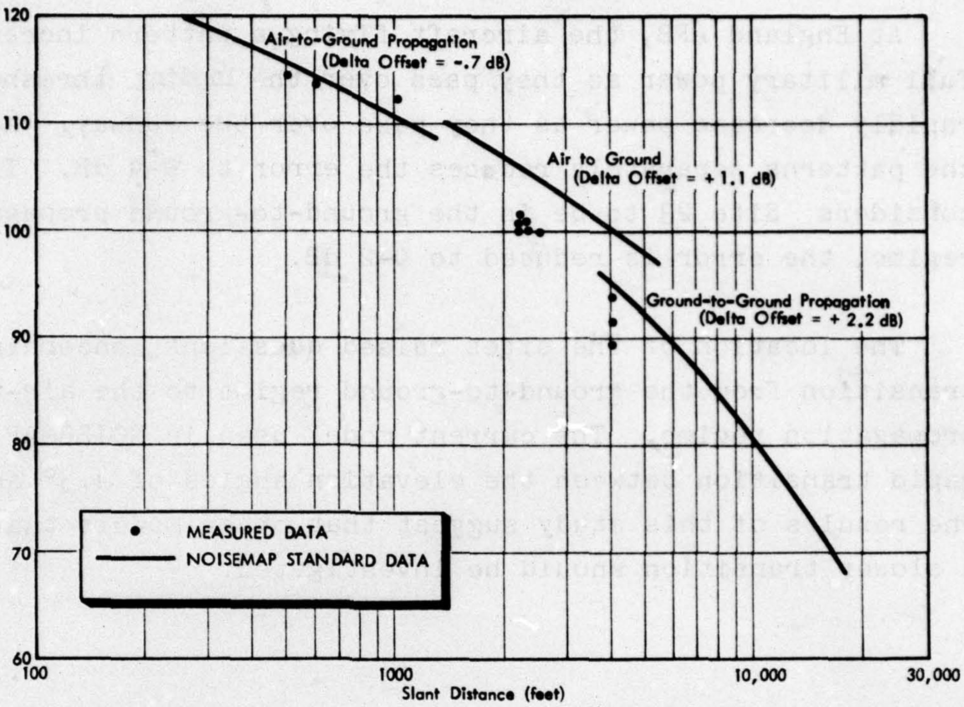

FIGURE 2. COMPARISON OF A-7 AIRCRAFT TAKEOFF NOISE DURING A DEPARTURE

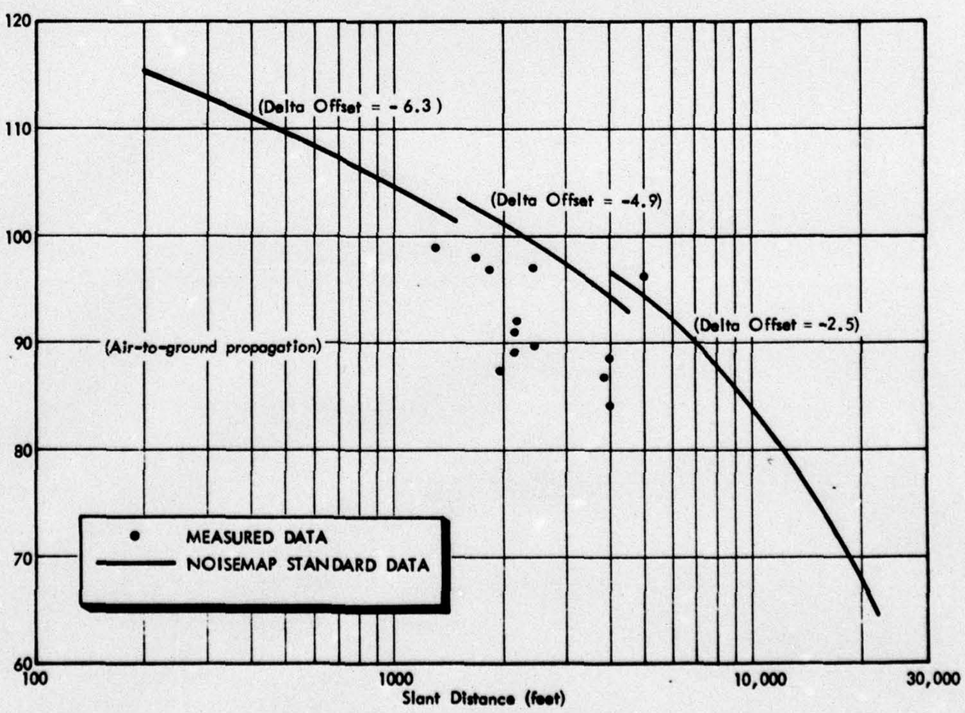

FIGURE 3. COMPARISON OF A-7 AIRCRAFT TAKEOFF NOISE DURING A PATTERN

At England AFB, the aircraft flying a pattern increase to full military power as they pass over the landing threshold, but rapidly decrease power as they pass over the runway. Modeling the patterns separately reduces the error to 0-4 dB. If one considers Site 23 to be in the ground-to-ground propagation regime, the error is reduced to 0-2 dB.

The location of the sites raised questions concerning the transition from the ground-to-ground regime to the air-to-ground propagation regime. The current model used in NOISEMAP makes a rapid transition between the elevation angles of 4.3° and 7.2°. The results of this study suggest that other models that make a slower transition should be investigated.

VALIDATION OF LANDING NOISE LEVELS

Travis Air Force Base in Fairfield, California, was selected for making landing noise measurements. The measurements were made between August 4, 1976 and August 24, 1976.

FIELD MEASUREMENTS

The normal runway used for landings at Travis AFB is 21L. Four measurement locations were selected along the runway. Three of these were directly under the flight path. The fourth was off to the side. The locations numbered 30, 31, 32 and 33 are shown in Figure 4. Table 8 shows the distances to each of the sites. A landing profile was generated from altitudes written on the operation slips. The average altitude at the TVOR (VHF omni-directional range transmitter, 5.5 N. miles from the end of the runway) is 1,900 feet.

The three basic aircraft using Travis AFB are the C-5A, C-141 and the KC-135. A variety of other military and civilian aircraft also use the base.

The aircraft typically flew past all measurement sites, except aircraft flying in the VFR (visual flight rule) pattern. Between 20-45% of operations flew the VFR pattern depending upon the type of aircraft. These aircraft do not pass over Sites 31 and 32.

Operational data were compiled from operations slips maintained by the tower and the radar approach control, RAPCON. Recorded from the slips were the time of day, the type of aircraft, the type of operation, and the altitude of the aircraft at the TVOR. Table 9 summarizes the operations that were observed during the measurement period. The annual average operations were taken from the AICUZ Phase II Report and are also given. During the measurement period, operations were below normal.

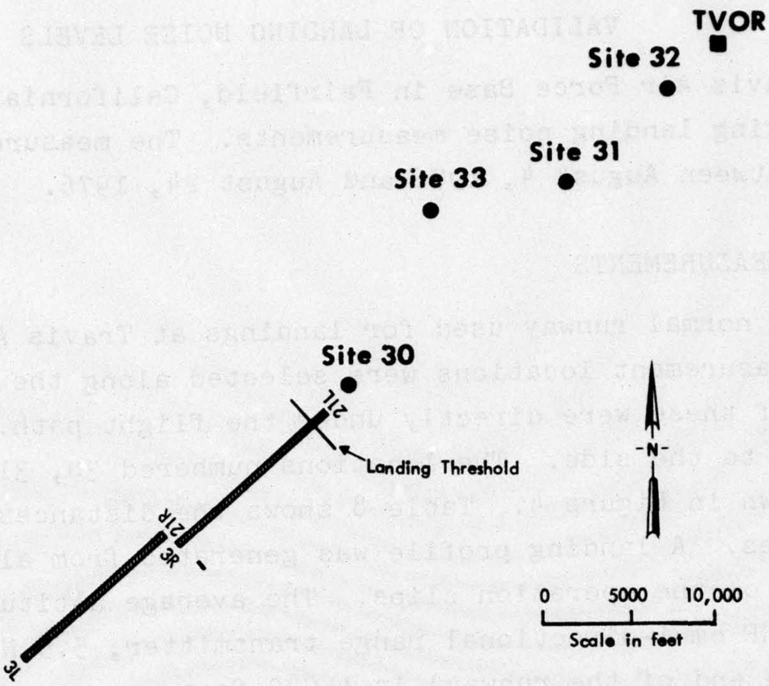

FIGURE 4. LANDING NOISE MEASUREMENT LOCATIONS, TRAVIS, AFB

TABLE 8

DISTANCE TO THE LANDING NOISE MEASUREMENT SITES

Site Number	Distance from Landing Threshold (Feet)	Distance Perpendicular To Runway (Feet)	Altitude of Aircraft (Feet)	Slant Distance to Aircraft (Feet)
30	2970	0	210	210
31	20625	0	1165	1165
32	29200	0	1627	1627
33	13800	4323	796	4395

TABLE 9

SUMMARY OF AIRCRAFT LANDING AT TRAVIS AFB*

Date	C-5A	C-141	KC-135	Other 4 Eng.Jets	Other 3 Eng. Jets	Other 1 & 2 Eng. Jets
8/4	35	22	5	3	0	6
8/5	42	59	5	2	0	9
8/6	35	46	12	11	0	9
8/7	58	32	10	6	2	3
8/8	33	29	0	7	1	1
8/9	37	62	21	4	0	10
8/10	26	53	27	8	0	1
8/11	35	40	24	4	0	8
8/12	39	70	29	9	0	13
8/13	48	58	20	5	0	11
8/14	45	22	10	6	0	1
8/15	57	51	6	1	1	1
8/16	33	59	11	5	0	4
8/17	54	35	23	15	0	5
8/18	32	50	12	5	0	5
8/19	45	33	11	3	0	10
8/20	33	30	16	4	0	22
8/21	29	43	2	5	0	8
8/22	25	25	5	3	2	15
8/23	7	42	15	4	1	23
8/24	31	43	12	4	0	11
8/25	10	33	16	2	1	15
8/26	6	9	4	1	0	1
Avg. Oper. 8/4 - 8/26	34.6	41.1	12.9	5.1	.4	8.4
Annual Avg. Oper.	46.6	57.8	36.8	2.1	-	12.1

* Aircraft in a pattern were assumed to perform a landing each cycle.

The baseline noise data were retrieved from NOISEFILE and are shown in Table 10. Corrections were made for speed and power. The percent of flights that performed a VFR pattern and thus did not pass over sites 31 and 32 were obtained from the Travis Phase II AICUZ Report. Corrections to the HNLs were made for these two sites based upon these percentages. The corrections to the levels are shown in Table 11 and the final noise levels used are in Table 12.

Standard day meteorological conditions were assumed in the predicted noise levels. The atmospheric absorption associated with actual temperature and humidity measured at the base was less than standard conditions. This would result in a higher predicted noise level. In the morning hours, the increase would be 0.2 to 0.5 dB per 1000 feet at 1000 Hertz. During midday, the increase in predicted values would be 0.0 to 0.3 dB per 1000 feet. This would slightly increase the difference between measured and predicted values.

A few minor problems occurred during the measurements. Rain caused a loss of data at some sites. High wind speeds required that the threshold be set higher than normal. This was not a problem except at Site 33 which was a substantial distance from the flight track.

DATA ANALYSIS

Operations were divided into six categories, C-5s, C-141s, KC-135s, other four-engine aircraft, other three-engine aircraft and other one- or two-engine aircraft. The 707 was considered typical of other four-engine aircraft. The 727 was used for three engine jets. The C-9 represented the other one or two engine jets.

TABLE 10

BASELINE NOISE DATA FOR TRAVIS AFB FROM NOISEFILE

Site	Slant Distance (Feet)	SEL (dB) C-5	C-141	KC-135	707	727	C-9
30	210	119.3	112.1	115.2	111.0	104.0	103.9
31	1165	108.0	99.7	104.9	97.5	91.1	91.8
32	1627	105.4	96.7	102.8	94.1	88.0	89.1
33	4395	93.6	83.4	94.7	82.6	76.9	79.4

TABLE 11

PREDICTED ADJUSTMENTS TO NOISE LEVELS

	C-5	C-141	KC-135	707	727	C-9
Speed Correction (dB)	+1.15	+ .5	+ .6	+ .4	+ .3	+1.1
Power Correction (dB)	-1.93	0	+4.0	- .1	+ .3	+1.0
Operations Correction (Sites 31 & 32) (dB)	-1.87	-1.1	-2.4	- .2	- .3	- .3

TABLE 12

PREDICTED NOISE LEVELS USED FOR TRAVIS AFB

Site Number	C-5	C-141	KC-135	707	727	C-9
30	118.5	112.6	119.8	110.3	104.9	106.0
31	105.3	99.1	107.1	96.6	91.7	93.6
32	102.7	96.1	105.0	93.2	88.6	90.9
33	92.8	83.9	99.3	81.9	77.8	81.5

The data for power settings and speed were obtained from base personnel at the time of this analysis. The data differed from the information available in the AICUZ Phase II Report used at the base. The largest difference was for the KC-135 and the C-141.

HNL values were calculated for all four sites using actual numbers of aircraft operations. These values are compared with measured values in Table 13. As can be seen, excellent agreement was achieved at Sites 30, 31 and 32. The difference at Site 33 was about 4 dB. This could be the result from ground-to-ground propagation effects or from fuselage shielding. Another possibility is that the difference is related to the high wind speeds that occur at Travis AFB. Reviewing individual events, some show noise levels very near to the expected levels while others are substantially below. Also, the noise levels at Site 33 appear to fluctuate more than at other sites. Verification that wind is the cause would require detailed meteorological measurements.

Analog measurements of C-141 aircraft are compared with data from NOISEFILE in Figure 5. A difference of ± 5 dB was observed. Since the measurements were made directly under the flight path, the differences probably result from variations in power settings and air speed.

CONCLUSIONS

NOISEMAP computer predictions of noise from aircraft approaching the runway are high by 0 to 1.1 dB for sites along the flight path. The predicted levels at the sideline site were 4.0 dB high. No definite conclusions could be drawn about the cause of the difference. It was found that obtaining accurate operational data was necessary to achieve good agreement with measured data.

TABLE 13

COMPARISON OF MEASURED AND PREDICTED LANDING NOISE LEVELS

SITE 30

Time of Day	Number of Samples	Energy Average HNL Pred. (dB)	Energy Average HNL Meas. (dB)	Energy Average HNL Diff. (dB)	Mean Arithmetic Difference (dB)	Standard Deviation (dB)
Day	150	89.1	88.3	.7	3.3	8.8
Evening	38	88.2	89.8	-1.7	-1.6	4.8
Night	77	87.9	88.5	- .5	2.0	9.3
24 Hour	265	88.6	88.6	0	2.3	8.6
			SITE 31			
Day	126	75.8	74.7	1.1	3.4	7.9
Evening	29	75.1	76.9	-1.8	-2.3	5.3
Night	65	75.6	72.9	2.7	3.8	7.5
24 Hour	220	75.6	74.7	1.1	2.7	7.7
			SITE 32			
Day	158	72.9	73.7	- .9	3.3	7.6
Evening	37	72.8	73.1	- .3	1.2	6.2
Night	82	73.1	70.8	2.3	5.1	9.6
24 Hour	277	73.0	73.0	0	3.6	8.1
			SITE 33			
Day	89	64.5	60.7	3.8	5.5	7.0
Evening	25	62.2	58.4	3.8	4.6	5.7
Night	51	66.9	62.8	4.0	5.9	10.2
24 Hour	165	65.2	61.3	3.9	5.5	7.9

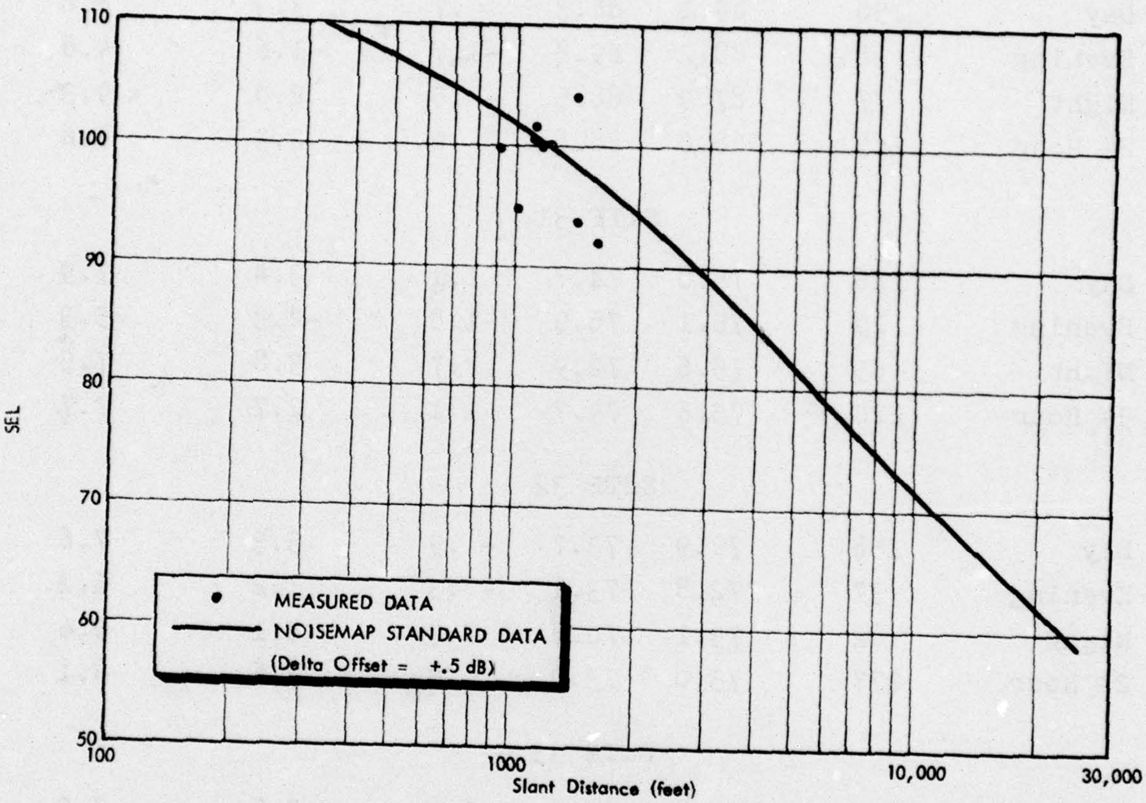

FIGURE 5. COMPARISON OF C-141 AIRCRAFT LANDING NOISE

VALIDATION OF PATTERN NOISE

Noise from the downwind leg of patterns was measured at Barksdale Air Force Base in Shreveport, Louisiana. The measurements were made between February 26, 1976 to March 12, 1976.

FIELD MEASUREMENTS

A single runway (Runway 14/32) is used at Barksdale. Aircraft flying patterns from either end of the runway use the same flight tracks to the east of the runway. Larger aircraft typically fly a pattern that is approximately 6 miles wide,* while smaller aircraft fly a path about 4 miles wide. The flight paths are shown on Figure 6.

Three measurement locations were selected, as shown in Figure 6. Site 10 was 6.1 miles to the side, Site 11 was 6.6 miles, while Site 12 was 6.9 miles. The sites were selected to minimize interference from activity near the runway. The measurement sites were all on base property in areas that were undeveloped.

Three aircraft commonly fly patterns at Barksdale AFB. They are the B-52, KC-135 and A-37/T-37. The B-52s and KC-135s fly the wider pattern.

Operational data were collected by base personnel. For each aircraft flying a pattern, the time of day and the type of aircraft were recorded. It was estimated that the aircraft was on the downwind leg about ten minutes after takeoff. Table 14 shows a summary of operations during the measurement period. This

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* The width is the lateral displacement of the nominal traffic pattern flight track measured from the runway centerline.

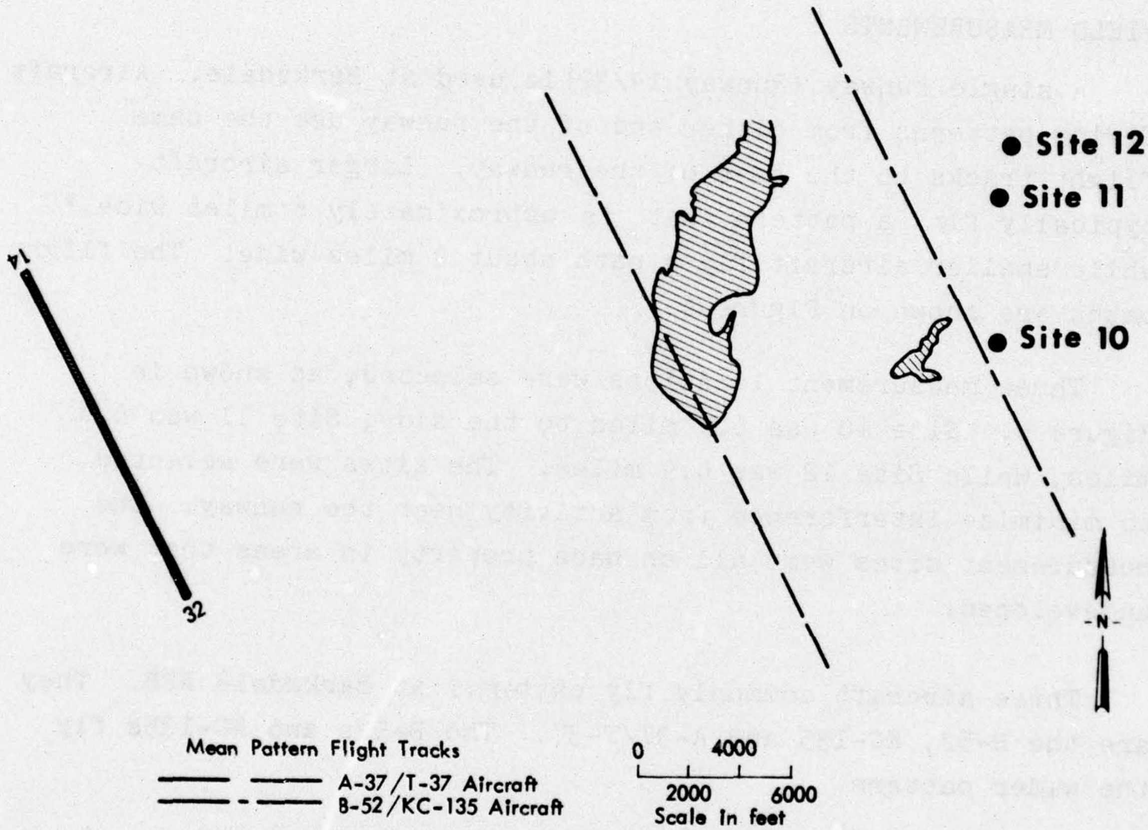

FIGURE 6. PATTERN NOISE MEASUREMENT LOCATIONS BARKSDALE AFB

TABLE 14

SUMMARY OF PATTERN FLIGHTS BARKSDALE AFB

Date	B52	KC135	Other	T37/A37
2/26	6	25	19	15
2/27	13	30	8	40
3/1	9	17	32	48
3/2	13	28	15	38
3/3	0	0	41	0
3/4	7	11	5	9
3/5	10	11	3	55
3/6	-	-	-	-
3/7	-	-	-	-
3/8	3	2	8	0
3/9	14	32	20	64
3/10	11	33	50	55
3/11	13	18	28	62
3/12	13	20	6	37
Avg. Oper. 2/26-3/12	9.3	18.9	19.6	35.2
Annual Avg. (Reported 1973)	50	50	24	60

is compared with average operational data from 1973. The annual operational data were taken from the AICUZ Phase II Report prepared for Barksdale AFB.

Radar tracings were made for two days. This provided information on the sideline distance and altitude on the downwind leg.

Heavy rains during the measurement period caused some loss of data. A limited number of analog measurements were made. The tall trees prevented getting good pictures for some of the analog measurements. However, the trees were not dense enough to significantly affect the noise levels.

DATA ANALYSIS

For purposes of the analysis, the aircraft were classified into three types of aircraft, B-52s, KC-135s and other aircraft. The A-37/T-37 made up the majority of other aircraft and was considered representative.

Six flight tracks were assumed. They are 2.5, 3.5, 4.5, 5.5, 6.5 and 8.0 miles to the east of the runway. Based upon the radar tracing, an average altitude of 1800 feet was used. Table 15 displays the various slant distances.

Noise data were retrieved from the NOISEFILE for the three classes of aircraft. The values are shown in Table 16. Table 17 shows the tabulation of corrections used for speed and power. The final noise data used for each aircraft and flight track are shown in Table 18.

The data for power settings and speed were obtained from the base personnel. These differ substantially from data used in 1973 and 1974 for developing noise contours for the base.

TABLE 15

SLANT DISTANCES TO THE PATTERN NOISE MEASUREMENT SITES

	Distance to Measurement Sites (Feet)		
Flight Track	Site 10	Site 11	Site 12
1	19150	21839	23184
2	13902	16583	17925
3	8693	11349	12683
4	3693	6192	7494
5	2732	1912	2687
6	10136	7494	6192

TABLE 16

BASELINE PATTERN NOISE DATA FROM NOISEFILE

	SEL, dB		
Distance (Feet)	B-52	KC-135	T-37
1600	105.1	102.8	90.6
2000	103.4	101.1	88.8
2500	101.6	99.3	87.0
3150	99.7	97.4	85.0
4000	97.6	95.4	82.9
5000	95.4	93.3	80.7
6300	93.1	91.0	78.3
8000	90.6	88.5	75.7
10000	88.0	85.9	72.9
12500	85.1	83.0	69.8
16000	82.1	79.9	66.5
20000	78.8	76.6	62.8
25000	75.4	73.0	58.8

TABLE 17

PREDICTED PATTERN NOISE CORRECTIONS

	AIRCRAFT		
	B-52	KC-135	T-37
Assumed Speed (Knots)	160	155	160
Assumed Power (RPM)	86%	83%	73%
Speed Correction (dB)	-.6	+.1	-1.8
Power Correction (dB)	0	-7.3	-2.3
TOTAL CORRECTION (dB)	-.6	-7.2	-4.1

TABLE 18

PREDICTED NOISE DATA USED FOR PATTERN NOISE

B-52 SEL (dB)

Track Number	Site 10	Site 11	Site 12
1	79.1	77.2	76.4
2	83.5	81.1	80.2
3	89.3	86.1	84.6
4	97.9	92.7	90.9
5	100.4	103.2	100.5
6	87.3	90.9	92.7

KC-135 SEL (dB)

Track Number	Site 10	Site 11	Site 12
1	70.3	68.4	67.5
2	74.8	72.3	71.4
3	80.6	77.4	75.7
4	89.0	84.0	82.2
5	91.5	94.3	91.6
6	78.6	82.2	84.0

T-37 SEL (dB)

Track Number	Site 10	Site 11	Site 12
1	59.8	57.6	56.6
2	64.7	62.0	61.0
3	70.8	67.4	65.6
4	79.7	74.5	72.5
5	82.3	85.2	82.4
6	68.7	72.5	74.5

HNL values were calculated for each of the sites based upon actual operations. The aircraft were divided among the flight tracks in two different ways. "Observed" dispersion is based upon radar tracing made during two days. The percent of each aircraft type that were observed between 2 to 3 miles to the sideline were assigned to a flight track 2.5 miles to the side. Aircraft between 3 and 4 miles were assigned to a track 3.5 miles, etc. Each aircraft type is assigned differently. The percentages used are shown in Table 19.

The "simplified" dispersion assigned aircraft to a discrete flight track based on rules for coding operational information for NOISEMAP. From radar tracing, it was found that the aircraft flight tracks varied ± 3 miles about a mean path. According to the rules for coding flight tracks for NOISEMAP, 3 flight tracks should be used. Sixty percent of the flights were assigned to the mean path and 20% were assigned to single flight tracks ± 2 miles of the mean track. These percentages are shown in Table 20.

All predictions were made assuming standard day meteorological conditions. A study of actual meteorological factors indicated that the atmospheric absorption was slightly less than standard. Compared to standard day assumptions, actual air attenuation at 1000 Hz was 0.2 to 0.7 dB per 1000 feet in the early morning hours and 0.2 to 0.4 dB during the day. Using these attenuation values would increase the predicted noise levels slightly thus reducing the difference between predicted and measured values.

A comparison of calculated and measured data is presented in Tables 21 and 22 for the observed and simplified dispersion cases. As can be seen, the simplified dispersion more nearly matches the measured data than does the observed dispersion.

TABLE 19

PERCENTAGES OF AIRCRAFT USING THE FLIGHT TRACKS, OBSERVED DISPERSION

Flight Track	B-52	KC-135	T-37
1	0	5.6	13.3
2	16.7	22.2	6.7
3	38.9	33.3	40.0
4	22.2	22.2	26.6
5	16.7	5.6	6.7
6	5.5	11.1	6.7

TABLE 20

PERCENTAGES OF AIRCRAFT USING THE FLIGHT TRACKS, SIMPLIFIED DISPERSION

Flight Track	B-52	KC-135	T-37
1	0	0	20.0
2	0	0	0
3	20.0	20.0	60.0
4	0	0	20.0
5	60.0	60.0	0
6	20.0	20.0	0

TABLE 21

COMPARISON OF MEASURED AND CALCULATED PATTERN NOISE, OBSERVED DISPERSION

Time of Day	Number of Samples	Energy Average HNL Pred. (dB)	Energy Average HNL Meas. (dB)	Energy Average HNL Diff. (dB)	Mean Arithmetic Difference (dB)	Standard Deviation (dB)
SITE 10						
Day	49	61.6	66.8	-5.2	-3.1	7.6
Evening	6	55.1	54.9	.2	2.6	5.4
Night	7	59.7	62.8	-3.0	- .2	8.7
24 Hour	62	61.1	66.0	-5.0	-2.2	7.7
SITE 11						
Day	41	62.4	65.6	-3.2	-1.2	7.2
Evening	3	51.9	51.6	.3	- .2	2.4
Night	3	62.1	54.3	7.8	4.4	10.9
24 Hour	47	62.1	65.0	-2.9	- .8	7.3
SITE 12						
Day	40	60.0	64.6	-4.6	-1.6	9.3
Evening	3	49.4	51.3	-1.9	-1.7	3.1
Night	1	49.5	54.4	-4.9	-4.9	0
24 Hour	44	59.6	64.2	-4.6	-1.7	8.9

TABLE 22

COMPARISON OF MEASURED AND CALCULATED PATTERN NOISE, SIMPLIFIED DISPERSION

SITE 10

Time of Day	Number of Samples	Energy Average HNL Pred. (dB)	Energy Average HNL Meas. (dB)	Energy Average HNL Diff. (dB)	Mean Arithmetic Difference (dB)	Standard Deviation (dB)
Day	46	63.2	67.0	-3.8	-1.9	7.6
Evening	5	57.1	55.6	1.5	3.7	6.1
Night	7	61.6	62.8	-1.2	2.1	8.3
24 Hour	58	62.7	66.3	-3.6	- .9	7.7
SITE 11						
Day	38	66.3	65.9	.4	2.2	8.3
Evening	2	47.2	52.0	-4.8	-4.8	2.3
Night	3	65.6	54.3	11.3	9.9	9.3
24 Hour	43	66.1	65.4	.7	2.4	8.4
SITE 12						
Day	32	64.5	64.5	0	4.0	8.9
Evening	1	46.0	49.6	-3.6	-3.6	0
Night	1	55.5	54.4	1.1	1.1	0
24 Hour	34	64.3	64.2	0	3.7	8.8

Dispersions in the flight path appear to cause the differences. Sideline distances measured from the radar tracings were narrower than the reported flight tracks. The operations traced may be atypical, but this cannot be established without additional radar tracing. The simplified dispersion produced predictions that closely matched measured data, suggesting that the observed operations were atypical.

Analog data are compared with the NOISEFILE data in Figures 7 through 9. The NOISEFILE data were adjusted using the corrections in Table 17. The B-52, KC-135 and T-37 are shown.

CONCLUSIONS

The predicted noise levels using observed flight track dispersion were low by 3 to 5 dB. With the simplified dispersion model, the predictions were low by 0 to 3 dB. Thus, predictions based on the simplified dispersion model yielded the best agreement with measured data.

The observed flight track dispersion, based on radar tracking, was large, ± 3 miles for flights at a nominal height above ground of 1800 feet. However, the relatively short observation perceived may have led us to overestimate the actual dispersion occurring during the period of noise measurements. This emphasizes the need for obtaining accurate flight path information.

Again, it was found that obtaining accurate operating conditions (speed and power) is essential. An initial computer prediction was made based on the operating conditions used in developing the noise contours for the base in 1973. This resulted in predictions that were 10 to 15 dB higher than measured. More accurate operational data was then obtained and the predicted values were much closer to measured values.

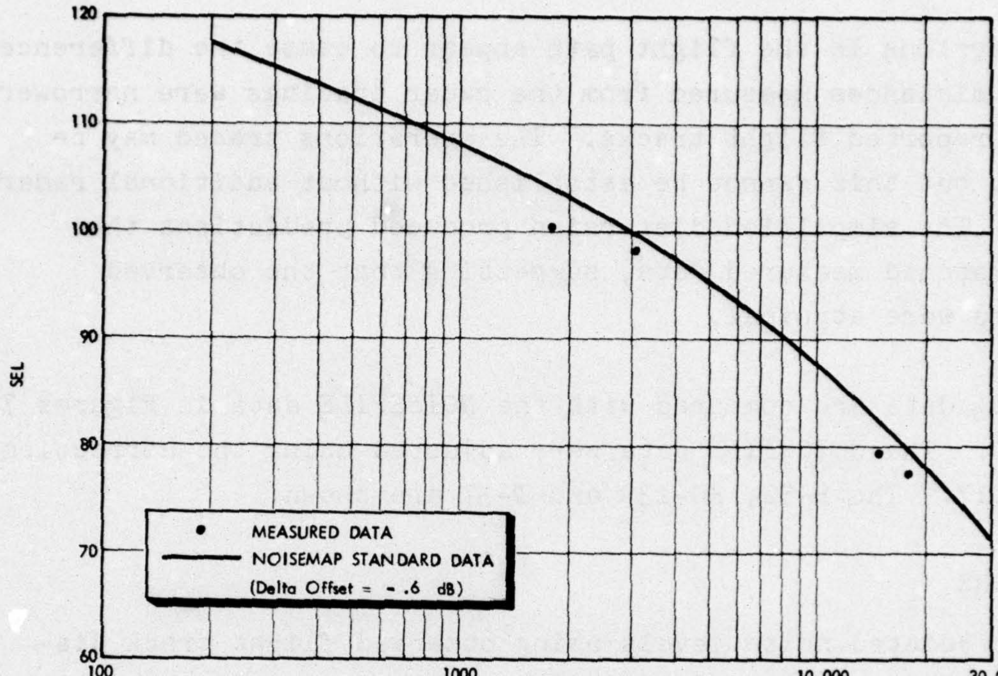

FIGURE 7. COMPARISON OF B-52 AIRCRAFT NOISE DURING THE DOWNWIND LEG OF A PATTERN

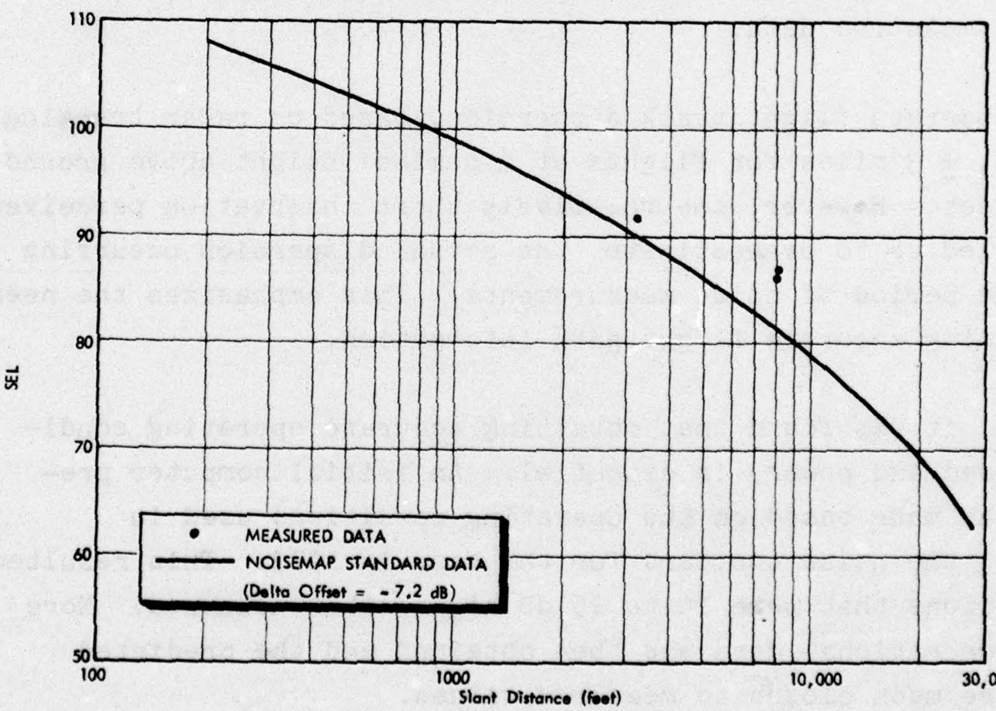

FIGURE 8. COMPARISON OF KC-135 AIRCRAFT NOISE DURING THE DOWNWIND LEG OF A PATTERN

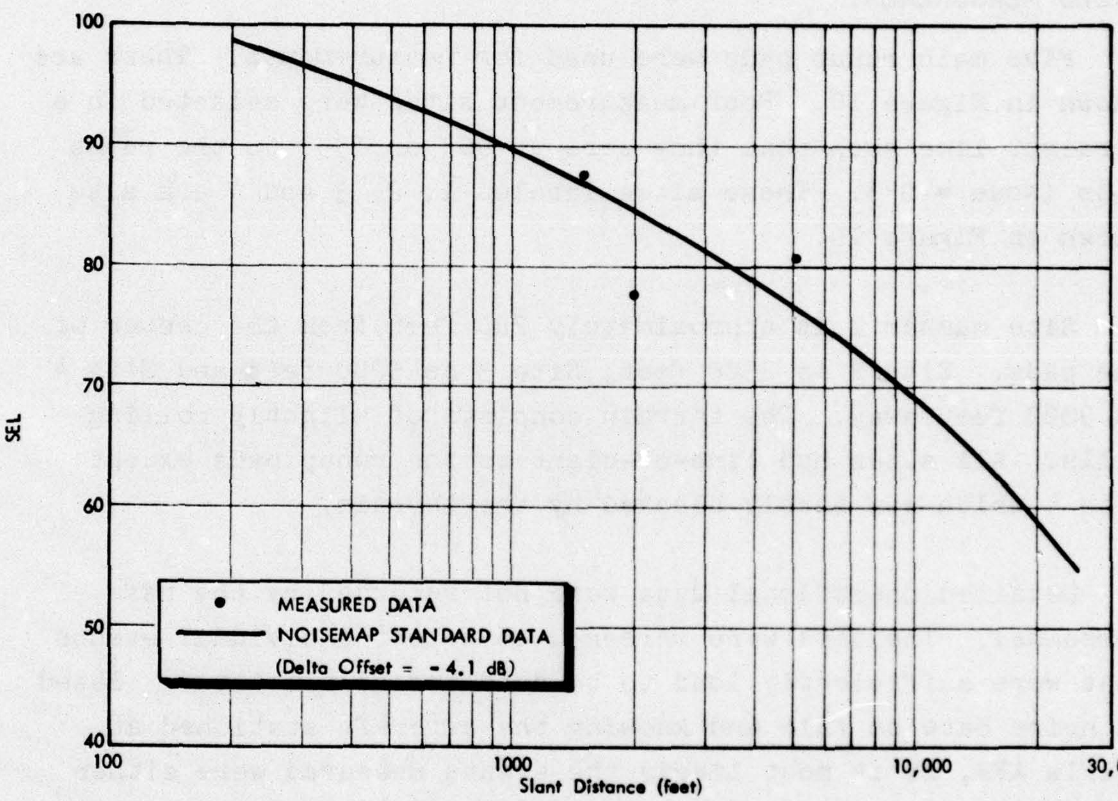

FIGURE 9. COMPARISON OF T-37 AIRCRAFT NOISE DURING THE DOWNWING LEG OF A PATTERN

VALIDATION OF RUNUP NOISE

Engine runup noise was measured at Nellis Air Force Base in Las Vegas, Nevada. The measurements were made between November 19, 1975 and November 26, 1975.

FIELD MEASUREMENT

Five main runup pads were used for measurements. These are shown in Figure 10. Four measurement sites were selected in a straight line such that they were at 90° or 135° to the runup pads (Nose = 0°). These sites labeled 1, 2, 3 and 4 are also shown on Figure 10.

Site number 1 is approximately 200 feet from the center of the pads. Site 2 is 2500 feet, Site 3 is 5200 feet and Site 4 is 9000 feet away. The terrain consists of slightly rolling hills. All sites had line-of-sight to the runup pads except Site 4 which was barely blocked by the terrain.

Detailed operational data were not recorded by the base personnel. The data were screened to select individual events that were sufficiently loud to be detected at all sites. Based on noise data on file and knowing the aircraft stationed at Nellis AFB, it is most likely the events measured were either F-111s or T-38s. Furthermore, the events were probably either at military power or afterburner power.

DATA ANALYSIS

SEL values were determined from the measurements made at Nellis AFB. First, events were identified from Site 1 which was only 200 feet from the runup pads. Since the noise levels at this site were high, it was easy to identify actual events. Only events with an SEL greater than 110 dB were used. The

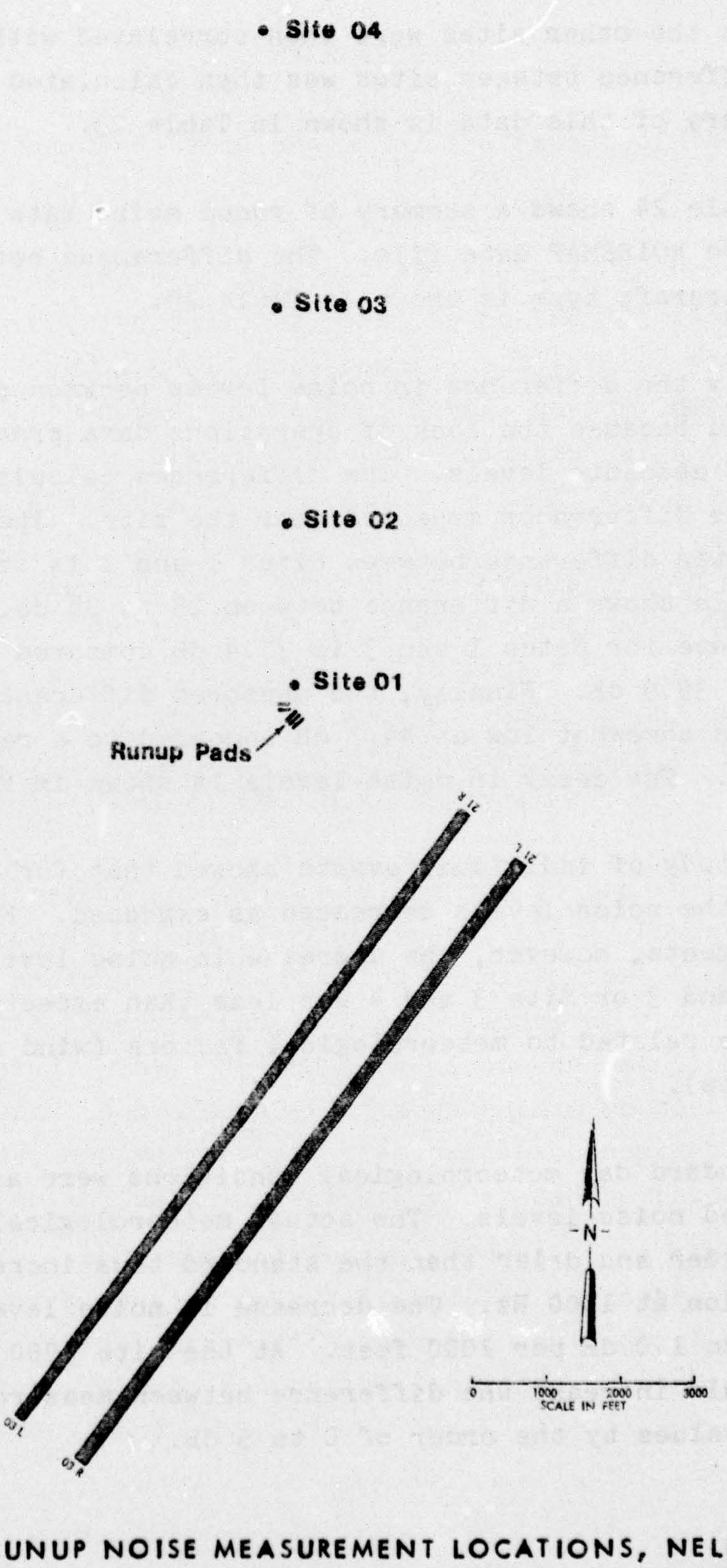

FIGURE 10. RUNUP NOISE MEASUREMENT LOCATIONS, NELLIS AFB

data at the other sites were then correlated with Site 1. The difference between sites was then calculated and averaged. A summary of this data is shown in Table 23.

Table 24 shows a summary of runup noise data based upon the standard NOISEMAP data file. The differences between sites for each aircraft type is shown in Table 25.

Only the difference in noise levels between sites could be compared because the lack of operations data precluded calculation of absolute levels. The differences calculated agreed well with the differences measured near the site. The measured arithmetic difference between Sites 1 and 2 is 28.9 dB. The data file shows a difference between 25 to 28 dB. The measured difference for Sites 1 and 3 is 37.4 dB compared to a range of 36.6 to 39.9 dB. Finally, the measured difference between Site 1 and 4 is somewhat low at 44.7 dB compared to a range of 46.0 to 50.3 dB. The decay in noise levels is shown in Figure 11.

A study of individual events showed that for most measurements, the noise levels decreased as expected. For several measurements, however, the decrease in noise levels between Site 2 and 3 or Site 3 and 4 was less than expected. This might be related to meteorological factors (wind and temperature gradients).

Standard day meteorological conditions were assumed in the predicted noise levels. The actual meteorological conditions were colder and drier than the standard thus increasing air absorption at 1000 Hz. The decrease in noise levels was 0.5 dB to 1.0 dB per 1000 feet. At the site 9000 feet away, this would increase the difference between measured and predicted values by the order of 0 to 5 dB.

TABLE 23

SUMMARY OF RUNUP NOISE DATA

Site Number	Number of Samples	Energy Average SEL (dB)	Energy Average Difference From Site 1 (dB)	Mean Arithmetic Difference From Site 1 (dB)	Standard Deviation (dB)
1	75	127.0	0	0	0
2	59	100.7	-26.3	-28.9	6.3
3	72	91.5	-35.5	-37.3	6.5
4	48	86.7	-40.3	-44.7	7.9

TABLE 24

SUMMARY OF STANDARD AIRCRAFT RUNUP NOISE DATA

T-38 AL (dB)

	Military Power		Afterburner Power	
Distance	90° Heading	135° Heading	90° Heading	135° Heading
200	105.2	115.8	110.4	123.5
2500	78.8	90.5	84.7	98.4
5200	67.3	79.2	73.0	86.8
9000	57.5	68.9	63.5	77.5

F-111F AL (dB)

200	109.0	122.1	117.0	129.4
2500	80.9	95.1	89.7	102.0
5200	69.1	83.2	77.9	90.2
9000	58.7	73.4	67.3	78.9

TABLE 25

DIFFERENCES IN RUNUP SEL VALUES CALCULATED FROM STANDARD NOISEMAP DATA

T-38 AL Differences (dB)

Sites Compared	Military Power 90° Heading	Military Power 135° Heading	Afterburner Power 90° Heading	Afterburner Power 135° Heading
1-2	26.4	25.3	25.7	25.1
1-3	37.9	36.6	37.4	36.7
1-4	47.7	46.9	46.9	46.0

F-111F AL Differences (dB)

Sites Compared	Military Power 90° Heading	Military Power 135° Heading	Afterburner Power 90° Heading	Afterburner Power 135° Heading
1-2	28.1	27.0	27.3	27.4
1-3	39.9	38.9	39.1	39.2
1-4	50.3	48.7	49.7	50.5

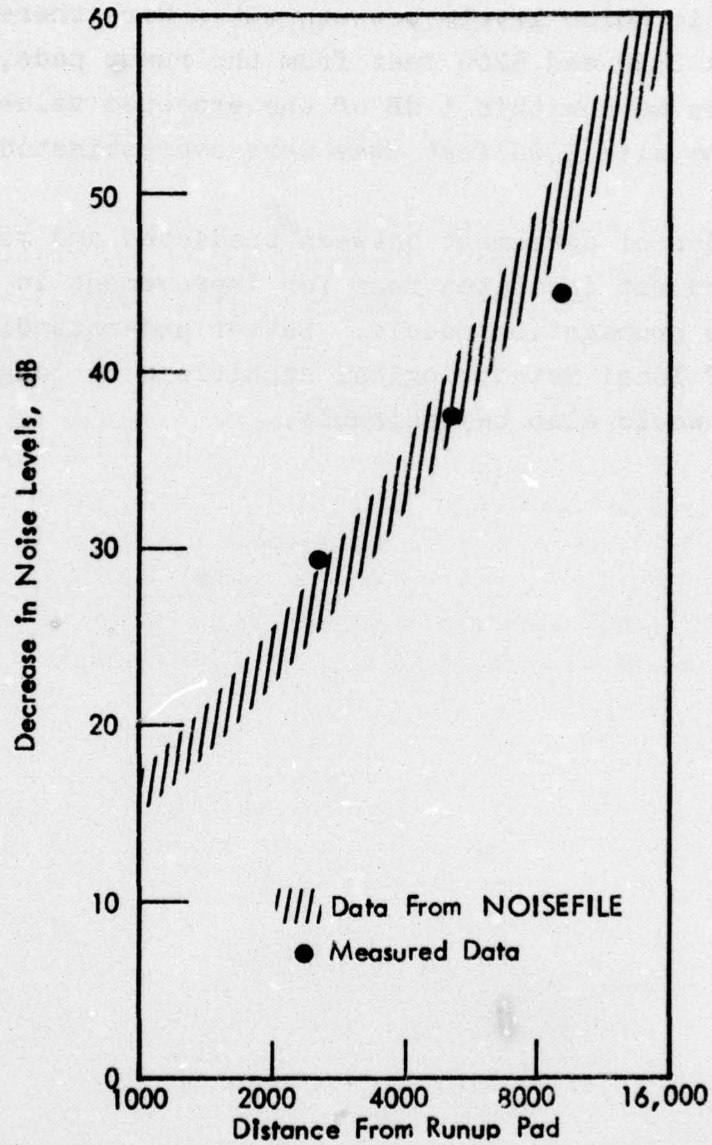

FIGURE 11. REDUCTION OF RUNUP NOISE WITH DISTANCE

CONCLUSIONS

Since data on the types of aircraft and power settings were not available, comparison of absolute levels was not possible. The changes in noise levels between sites were therefore studied. At the sites 2500 and 5200 feet from the runup pads, the predicted levels were within 1 dB of the expected values. The levels at the site 9000 feet away were overestimated by 2 - 5 dB.

This order of agreement between predicted and measured levels is quite good but indicates room for improvement in current over-ground noise propagation models. Better understanding of the influence of local meteorological conditions on long-distance propagation would also be desirable.

SUMMARY

In general, the algorithms used in NOISEMAP provided predictions that agreed well with data measured during this study. Comparisons of measured with predicted data provide no grounds for specific recommendations on immediate changes to present NOISEMAP algorithms. However, the observed differences, particularly for positions off to the side of flight tracks and at large distances from ground runups suggest the need for further study of models for predicting noise for ground-to-ground propagation and for the transition between air-to-ground and ground-to-ground propagation (including possible shielding effects).

These verification studies clearly confirm that obtaining accurate data on operational procedures is essential in obtaining good results. Operational data taken from existing reports used to develop day night level contours frequently were different from data obtained from the base during the verification studies. Information on aircraft power settings and speed was most commonly in error.

Measurements of takeoff noise at England AFB suggest that aircraft flying in patterns and doing missed-approaches should be modeled differently than aircraft making regular departures since the speed and power settings differ. Modeling all departures as takeoffs produced estimates that were two to four dB higher than measured data. Modeling the pattern reduced this difference to 0 to 4 dB.

At Travis AFB, NOISEMAP estimates for landings were within 0 to 1.1 dB for sites under the flight path. Levels at sideline positions were over-predicted by 4 dB.

Predictions of noise for the downwind leg of patterns at Barksdale AFB was within 0 to 3 dB of measured values. Predictions were improved by obtaining more accurate descriptions of dispersion and of the operational characteristics of the aircraft flying the pattern.

From measurements of ground runup noise at Nellis AFB, it was found that the prediction of changes in noise levels with distance was accurate to within 1 dB for sites up to 5000 feet from the engine. At larger distances, the model overestimated the decrease in levels with differences amounting to 4 dB at 9000 feet.

Most of the measurements were taken under conditions where the air absorption did not differ significantly from the standard day conditions. Hence, adjusting data for the actual air absorption would not have materially altered the comparisons.

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TEST PLAN FOR VALIDATION OF AIR BASE NOISE EXPOSURE CONTOURS

INTRODUCTION

This technical appendix outlines a test plan for validation of air base noise exposure contours which result from aircraft flight and ground operations.

The USAF community-aircraft noise exposure computerized prediction program computes and draws contours of equal NEF or DNL values to represent the noise from operations at an airport.[A-1,A-2*] The prediction program relies on input information from a number of sources. Basic noise and aircraft performance data are usually stored in the computer program; information on number of operations and flight tracks is dependent upon the particular airport under study. The prediction program also incorporates a number of assumptions in terms of the aircraft noise modeling. For example, assumptions are made in regard to air-to-ground, ground-to-ground propagation and the transition between modes of propagation.[A-3]

Questions naturally arise as to the accuracy of the computer program and of the resulting noise contours. Validation becomes more critical as major air base decisions are involved. Validation will also become more pertinent with the increasing use of DNL contours since DNL values can be quite readily monitored in the field. A number of civil airports are installing monitoring equipment capable of measuring DNL continuously. And, community and/or local governmental agencies are urging installation of monitoring systems near at least several military air bases in California.

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* References are listed together at the end of the text.

Validation may be reviewed in two different contexts.

(a) The validation of contours for a particular airfield or operations to determine how well the measured noise environment agrees with the predicted environment.

(b) More general validation to determine the reason why the field measurements either agree or disagree with the predictions, with the validation analyses in sufficient depth and accuracy to determine whether or not the basic input for the NOISEMAP model was valid and whether the assumptions in the model were actually realized for the particular field situation.

The major emphasis in the report is towards general validation, with the aim of developing specific recommendations for improving the accuracy of the prediction procedures and applications.

TECHNICAL BACKGROUND AND DISCUSSION

The noise exposure prediction program is generally applied to develop contours representing average noise exposure over an entire year. However, the actual noise environment around an airport varies from hour to hour and from day to day. Measurements over any one day rarely match exactly conditions averaged over a year. In this sense, each set of daily validation data represents a series of snapshots of a "landscape" that is changing in detail from day to day and season to season. Thus, one must collect much more information, in addition to the basic noise measurements, in order to obtain sufficient information for in-depth validation studies of contours based on yearly averages.

Since the noise environment is a variable quantity, statistical analyses must be used to determine the number of samples required to establish the noise environment levels to a given degree of precision, or, conversely, to determine the confidence limits of sample noise data.

There are a number of inputs to the prediction program which are subject to check through validation studies:

1. Aircraft noise vs distance curves (per aircraft type)
2. Takeoff and landing profiles for aircraft (including appropriate engine power settings)
3. Aircraft flight tracks over ground
4. Flight path dispersion
5. Volume of aircraft operations per aircraft type per time period
6. Sound propagation assumptions
   a. Air-to-ground
   b. Ground-to-ground
   c. Transitions from air-to-ground to ground-to-ground propagation

7. Atmosperic absorption (seasonal and daily changes)
8. Sideline noise radiation and propagation (takeoff and landing roll)
9. Aircraft model assumption
   a. Noise source shielding in multi-engine aircraft
   b. Noise radiation pattern assumptions

A review of the factors listed above reveals that not all will be of equal importance or significance for any given phase of airport operations. And, any one airport may include only a limited number of aircraft and types of operations. This suggests defining validation studies in terms of "situations" where each situation emphasises one or several elements of the prediction model input.

The process of selecting "situations" for validation must generally consider not only the technical factors of interest but the relative importance of the "situation" in determining noise exposure contours at typical Air Force bases.

Four basic operational "situations" can be defined. Each can be further broken down as shown below:

Takeoff Operations
- Close-in (0 to 2 miles from brake release)
- Intermediate (1.5 to 4 miles from brake release)
- Extended (3 to 10+ miles from brake release)

Approach Operations
- Close-in (landing roll to 1 mile from landing threshold)
- Intermediate (1 to 4 miles from landing threshold)
- Extended (3 to 10 miles from landing threshold)

Pattern Operations

. Well defined flight track

. Widely dispersed flight tracks

Ground Runup Operations

. Operations at specific sites

. Dispersed operations

The number of situations can also be expanded by groupings of type of aircraft (bomber vs fighter, etc.) and by considering repeat measurements of a given operational situation to study seasonal effects.

Since study of any given situation may involve from 20 to over 60 instrument days to collect sufficient noise data, it is evident that any proposed program cannot cover *all* situations of interest. A priority listing of situations must be developed which takes into account both:

(a) The relative importance to air base noise environments and air base/community annoyance concerns

(b) The relative potential contribution to improved prediction models

Taking the above into account, it is recommended that initial validation "situations" be selected from the following list:

Takeoff -- Intermediate and extended

Approach -- Intermediate and extended

Pattern -- Widely dispersed flight tracks

Ground Runup -- Operations at specific sites

This listing omits some situations which are of great physical complexity and technical interest, but which generally are not major contributors to the total air noise environment.

Estimates of the precision of a set of field measurements can be obtained by application of basic statistics, considering each data point as an independent sample of the fluctuating noise environment. From a set of measurements, one can calculate the sample standard deviation, and then the confidence interval, as shown in Figure A-1. This figure can also be used to estimate the number of measurements that will be needed to achieve a given precision of measurement.

In applying Figure A-1 one must distinguish between the need to establish either 24-hour noise exposure values (DNL) or individual noise level (SEL) measurements from a given operation, since the degree of variability and time required for measurement may be vastly different. For example, an air base may have a wide variation in the number of operations and in the choice of flight path used on a day to day basis. Therefore, it may take a considerable period of time, perhaps several weeks, to establish field noise DNL values to a given degree of confidence, since one can accumulate only one DNL value for 24 hours of measurements. However, one may be able to determine noise levels for a given aircraft operation to a desired confidence level in one or two days if a large number of the operations occur each day.

In verifying the noise prediction model, the critical metric will be the difference between the predicted and measured noise levels (whether it be for single event levels or for 24-hour descriptors such as DNL). For example, a measured DNL value obtained near an air station would be compared with a predicted DNL (based on the operations observed during the day in question) and the difference determined.

Reflected in this difference, of course, will be the predictive model's best efforts to account for such variables as numbers of operations, mix of aircraft, flight path dispersion, individual aircraft noise levels, etc. (A simple application of this consideration occurs for air base operations where there are significantly fewer operations on weekends than on weekdays.)

If the measurement/prediction process were repeated over a number of days, some random variation in the difference values would be observed. The important question to be answered is whether or not the average difference is sufficiently close to zero so that one could accept (or reject) the notion that the long term average noise environment is predictable from the computer model.

Independent of the DNL comparison, it is desirable to examine SEL values of major aircraft in a similar manner. That is measured and predicted SEL values would be compared for a number of aircraft types. This analysis is useful

(1) to insure that DNL agreement did not arise simply out of compensating errors between noise level assumptions of two or more aircraft or
(2) to determine whether DNL non-agreement may have resulted from discrepancies in noise level assumptions.

In planning verification measurements, it is useful to be able to estimate the anticipated variability in the noise data, and thus to determine the approximate sample size necessary to achieve the accuracy of the study. Information acquired over the last several years as to the variability in observed 24 hour measurements (CNEL and DNL data) may be helpful in such planning. Figure A-2 shows the standard deviations for daily 24-hour measurements observed at 16 positions at 4 airports (3 civil and 1 military). The measurements at each position varied from a period of 13 days

to 193 days. Linear regression lines (standard deviation vs log of distance) have been fitted to the data to illustrate trends in the data. Note that the variability tends to increase only slowly as a function of distance. Typically, for distances up to 1000 feet one can estimate the standard deviations to be on the order of 2 dB increasing to as much as 4 or 5 dB at distances of 5000 feet.

Note that the data shown in Figure A-2 is raw field data and has not been compared with any predicted values. Recent experience has shown, however, that a simple accounting for the number of daily operations (on a 10 log N basis) reduces the standard deviation by approximately one decibel. Thus, a full exercise of the predictive model should at least achieve comparable results, and sample sizes estimated from Figure A-2 should be conservatively large.

IMPLEMENTATION

The previous section discussion the framework of the validation test plan is built upon a foundation of comparing predicted and measured ncise exposure under a number of key air base operational "situations".

The "situations" can be broadly classed into three groups relating to typical air base activity.

- departures and arrivals
- closed loop practice patterns (including downwind leg of overhead approach)
- engine ground runups

Test plan strategies will vary somewhat from one "situation" class to the next, but will share the concept of comparing measured and predicted noise exposure at key ground locations on a day-by-day basis. Basically, each situation will be studied in the following manner:

- First, an airbase satisfying the situation requirements will be selected.
- Second, ground measurement locations will be chosen and noise monitor systems installed.
- Third, during the noise monitor period BBN and air base personnel will collect pertinent aircraft movement and meterological data. This data will be used in the NOISEMAP simulation model to calculate the predicted exposure at each measurement site for each day of noise monitoring.
- Fourth, at each site, the measured and predicted exposure will be compared and daily differences tabulated (ideally the average difference over the measurement period will be zero). Any statistically significant differences

(within the accuracy framework of the study) will be investigated and probable causes rank ordered as to their impact on the discrepancy.

In isolating potential discrepancies, the predictive model may be divided into three parts.

(1) Input data relating to local air station activity (flight path locations, number of aircraft, movements, aircraft mix, details of ground runup operations, etc.)

(2) Input data relating to aircraft noise and performance

(3) The computational model itself

It is convenient to think of the model in this framework since almost all of item (1) may be eliminated as a potential source of error so long as logs of pertinent air station activity are maintained during the noise monitor period. For example, for flight operations (including departures, arrivals, and closed loop practice patterns) detailed flight logs and radar trackings to establish aircraft flight patterns will be required. Likewise, for engine ground runups, a carefully maintained log of aircraft types and engine power settings under test will be needed. The above items are discussed in some detail in the test plan outline in the succeeding pages.

In preparing this plan, it has been assumed that the local air bases will provide manpower support to maintain the required operation logs.

A. Test Plan

1. Step 1 - Screen Candidate Air Bases for Satisfactory "Situation" Conditions

Under this step, candidate air bases would be screened for their suitability to evaluate departure and arrival noise exposure situations. At a minimum, it is anticipated that the following requirements must be met:

(a) Departures and Arrivals

1. local radar must be capable of charting aircraft flight paths immediately after liftoff (for departures) and to within 1/2 mile of threshold (for approaches)

2. expected runway use during noise monitor period must be greater than 95% in one direction

3. flight paths must be reasonably straight within 5 to 10 miles of the air station (depending upon the situation under study) with lateral dispersion one mile or less

4. reasonable day-to-day consistency in aircraft mix with fewer than 6 aircraft types dominating daily noise exposure

5. no altitude or power restrictions should be in effect within 5 to 10 miles of the air station

6. areas adjacent to flight paths must be suitable for noise monitor installation (i.e., showing promise of low background sound levels and devoid of major security problems)

(b) Closed Loop Patterns

1. Local radar must be capable of charting aircraft flight paths throughout the pattern immediately after liftoff to within 1/2 mile of threshold

2. Expected pattern use must be greater than 95% in one direction during the noise monitor period

3. Downwind leg must be reasonably straight with lateral dispersion of one mile or less

4. Fewer than 6 aircraft types dominating noise exposure in pattern

5. No unusual altitude restrictions or power management during downwind leg

6. Areas adjacent to midpoint of downwind leg must be suitable for noise monitor installation (i.e., showing promise of low background sound levels and devoid of major security problems)

(c) Ground Runups

1. Runup pads must have fixed tie-down points with no more than two possible aircraft headings

2. Runup pad use must be reasonably active on a day-to-day basis

3. Must be at least one pad with no engine power restrictions

4. Runup pad area must be suitable for installation of monitor system microphone 75 meters (250 feet) from source

5. Optimal noise monitor locations are on a line making 135° angle with aircraft axis (nose is 0°)--terrain within two miles of aircraft along this line must be reasonably flat and devoid of significant noise intrusions from other sources

6. Land areas described in (5) must be suitable for noise monitor installation (i.e., showing promise of low background sound levels, no intervening structures, no blast deflectors or suppressors, and devoid of major security problems)

In addition to the aforementioned items, seasonal weather conditions will also be reviewed for potential conflict with noise monitor instrumentation. Undesirable meteorological conditions would include frequent rain or fog, large extremes in temperature and humidity, and frequent winds in excess of 10 to 15 knots.

To facilitate the screening process, it is anticipated that reasonably up-to-date aerial photographs, base maps, and existing noise contour sets will be made available. After initial screening of this material, telephone contact will be made with the designated single point of contact to confirm the criterion points above. It is fully anticipated at this time that air stations can be selected without the necessity of an on-site visit.

2. <u>Step 2 - Selection of Measurement Sites</u>

Once the air base has been selected, field crews will be deployed to make final site selections and install instrumentation. Timing of the field work will be coordinated with base personnel to insure that

(1) Base personnel would be available to log necessary operations data during the noise monitor period and

(2) that no unusual air station activity is anticipated during the proposed noise monitor period.

The main thrust of the noise data acquisition program will be to obtain continuous 24-hour data at a number of key ground stations. These stations will collect only digitized, A-weighted sound level data. In addition, however, a limited number of direct analog recordings will also be obtained. This data will be recorded on analog tape, so that a complete spectral time-history of the noise source will be available for future reference.

(a) Departures and Arrivals

Fig. A-3 shows a typical array of noise monitor positions for departure and arrival monitoring. Note that monitor systems are deployed along a line perpendicular to the nominal flight path, with one system located near the mean path. Two to three additional systems would be used, with the most distant station positioned such that expected maximum A-levels from significant aircraft would be no less than 75 decibels. This lower limit provides adequate signal to noise ratio so that monitor systems can discriminate between aircraft and background sound levels. For moderately busy air stations (∿200 movements per day past the monitor stations) an LDN of 60 to 65 decibels may be expected.

(b) Closed Loop Patterns

Fig. A-4 shows a typical array of noise monitor positions for practice pattern monitoring. In this case, noise associated with the downwind leg of the pattern is to be measured. Instrumentation is deployed along a line perpendicular to the downwind leg and abeam the midpoint of the runway. Note that one monitor is located directly beneath the mean path with two or three additional systems located at greater distances from the flight path. As with departure and arrival monitoring, the most distant station would be situated such that maximum A-levels from significant aircraft would be no less than 75 decibels.

(c) Ground Runup Operations

Fig A-5 shows a typical array of noise monitor positions for ground runup operations. Note that the instruments are located along a line forming an approximate angle of 45° with the longitudinal axis of the aircraft (relative to the engine exhaust). Typically, this is the angle at which maximum sound

radiation from jet engines occurs at high engine power settings, allowing noise measurements to be made at maximal distances from the sound source.

In most cases, the closest microphone of the array will be placed 76 meters (250 feet) from the source. Accumulated noise records at this station will

(1) provide positive identification of those periods when the runup areas were in use and

(2) be obtained at the same reference distance as the predictive model data base.

The most distant microphone will be placed where the expected sound level for reduced power settings (not idle) would be 70 to 75 dB[A].

3. Step 3 - Collect Aircraft Movement and Meteorological Data

Concurrent with Step 2, work under Step 3 will also be undertaken. The two primary efforts under this task are

(1) to obtain radar trackings of pertinent aircraft flight movements and

(2) to log pertinent aircraft movements during the noise monitor period.

For all noise monitoring involving aircraft flight operations, limited radar tracking will be required. The purpose of the radar trackings is to establish the ground projection of the mean flight path being monitored and the extent of lateral dispersion about the mean. This tracking is most easily accomplished using a standard radar oscilloscope, clear plastic overlay, and grease pencil. The radar should be capable of generating a display to the scale of 1 inch per 2 n. miles. Aircraft flight tracks are then charted by following the radar

targets with the grease pencil. After a number of targets have been tracked, a network, similar to that shown in Fig.A-6 will develop. For the purposes of this study, flight tracks need not be monitored over the entire noise monitor period. Experience has shown that 30 to 50 flights are usually sufficient to establish the extent of the overflight area, and it is often possible to obtain this data in one day's time. It is anticipated that BBN staff will undertake this task with the cooperation of air traffic control personnel.

The collection of meteorological data will be a requirement during all noise monitoring. At a minimum, bi-hourly reports of

(1) wind speed and direction
(2) barometric pressure
(3) temperature and relative humidity

will be required. The Hourly Surface Weather Observations normally acquired by the base will fulfill this requirement.

Outlined below are the specific data collection requirements for each type of situation. A number of tentative log forms, to be maintained by Air Force base personnel, are included. It is assumed that local air base manpower would be made available to maintain these logs, with training to be provided by BBN staff.

(a) Departures and Arrivals

In order to achieve maximal benefit from the noise monitor data, a complete log of relevant flight activity over the one to two week noise monitor period will be required. Fortunately, this does <u>not</u> mean that every air station movement must be logged. Since the noise monitor systems will be monitoring aircraft on only one flight path, the

logs need only reflect operations on that path alone. Favorable past experience has been realized by placing an observer in the control tower equipped with log forms similar to those shown in Figs. A-7 & A-8 (either departures or arrivals, as appropriate to the situation under study). Note that each aircraft movement is a separate entry on the log form. Formation departures are indicated by ditto marks in the "TIME" column. Essentially, the only data required is (1) the time of day the movement occurred, (2) the type of aircraft involved and (3) any deviations from normal procedure. At the conclusion of each day, the detailed logs will be reduced to a simplified form, grouping aircraft movements by aircraft type and obtaining counts for each group. Typical daily summary sheets are shown in Figures A-9 and A-10. These daily summary sheets will provide the basic input data to the predictive model for comparison with the field measured data.

The observer's qualifications should include

(1) ability to recognize aircraft indiginous to the air base

(2) familiarity with local flight patterns.

BBN training should commence 3 to 4 days before installation of monitor systems to allow at least one to two days of practice data acquisition and review before monitoring begins.

(b) Closed Loop Patterns

For closed loop patterns traffic activity must be logged in a manner similar to departures and arrivals.

Using the special form shown in Fig. A-11 a control tower observer will log all flights using the downwind leg of the pattern. Each movement is logged by time-of-day, type of

aircraft, and the reason the aircraft is in the pattern (e.g. departure, overhead approach, pattern practice). At the end of each day, the detailed logs will be reduced to a simplified form, similar to those for aircraft arrivals shown in Figure A-10.

Observer qualifications are identical to those for logging departures and arrivals. Complete logs over a one to two week noise monitor period will be required.

(c) Ground Runups

Ground runup activity will be logged using forms similar to that shown in Figure A-12. One form will be completed for each day of noise monitoring at each runup pad of interest. Data to be entered on the log includes

(1) the type of aircraft (or engine type if a bare engine is being tested) using the pad,

(2) the time frame during which the pad was occupied,

(3) the total engine run time, and

(4) the percentage of time the engine was run at various power settings.

At this time we believe no special manpower requirements are necessary to complete these forms, other than coordination with maintenance test crews.

4. Step 4 - Comparison of Measured and Predicted Exposure

Once the noise monitor data has been processed and the predictive model exercised, a daily tabulation of predicted and measured DNL values (and the difference between them) will be compiled. This tabulation will provide the basic data to test whether or not there is a significant difference between prediction and measurement. This test will be performed in a straight forward fashion using

recognized statistical techniques. Should the difference be significant, then we would assume that there must be some underlying cause for this condition. The causes will, of course, be attributable to differences between the computer model (and perhaps the input data) and real life. Prime candidates for these differences include:

- aircraft performance (altitude profiles)
- aircraft noise level with distance
- aircraft power settings
- flight path dispersion
- sensitivity to a few noisy, non-typical operations.

Less likely candidates would include:

- inaccurate operations input to model

These candidates would be investigated using backup data obtained during direct observations by BBN personnel. For example, aircraft noise level versus distance curves would be checked using photographic distance data and noise monitor SEL values obtained at various distances from the aircraft. Should this analysis reveal significant differences between model input data, analog tape recordings would be analyzed to determine whether assumptions in frequency spectral content may have been the cause.

B. Summary of Air Station Manpower Requirements

The implementation section of this appendix outlines a number of tasks requiring support by Air Force personnel. Following is a review of these requirements.

1. Departure, Arrival, and Closed Loop Pattern Monitoring - Personnel sufficient to maintain a 24-hour, one man observation watch logging pertinent aircraft flight operations. Time frame may extend to as much as three weeks per situation.

2. Ground Runups -
Personnel to issue special forms to maintenance crews using runup areas under study. Time frame may extend to as much as three weeks per situation.

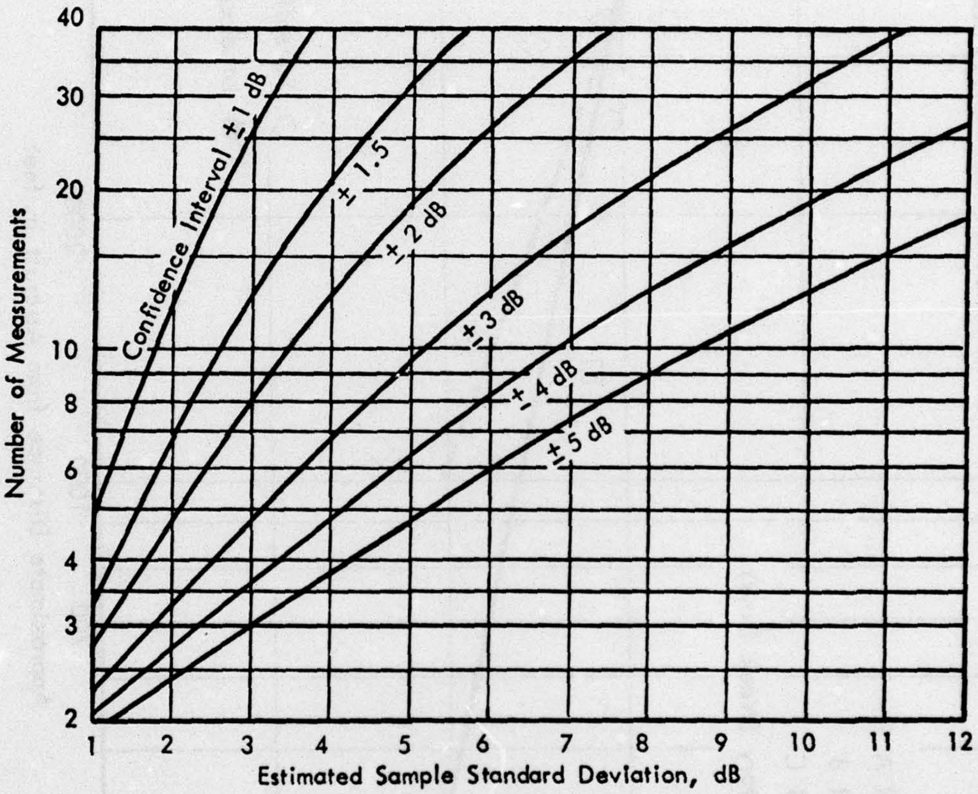

FIGURE A-1. GUIDE TO ESTIMATING SAMPLE SIZE FOR A 90 PERCENT CONFIDENCE INTERVAL

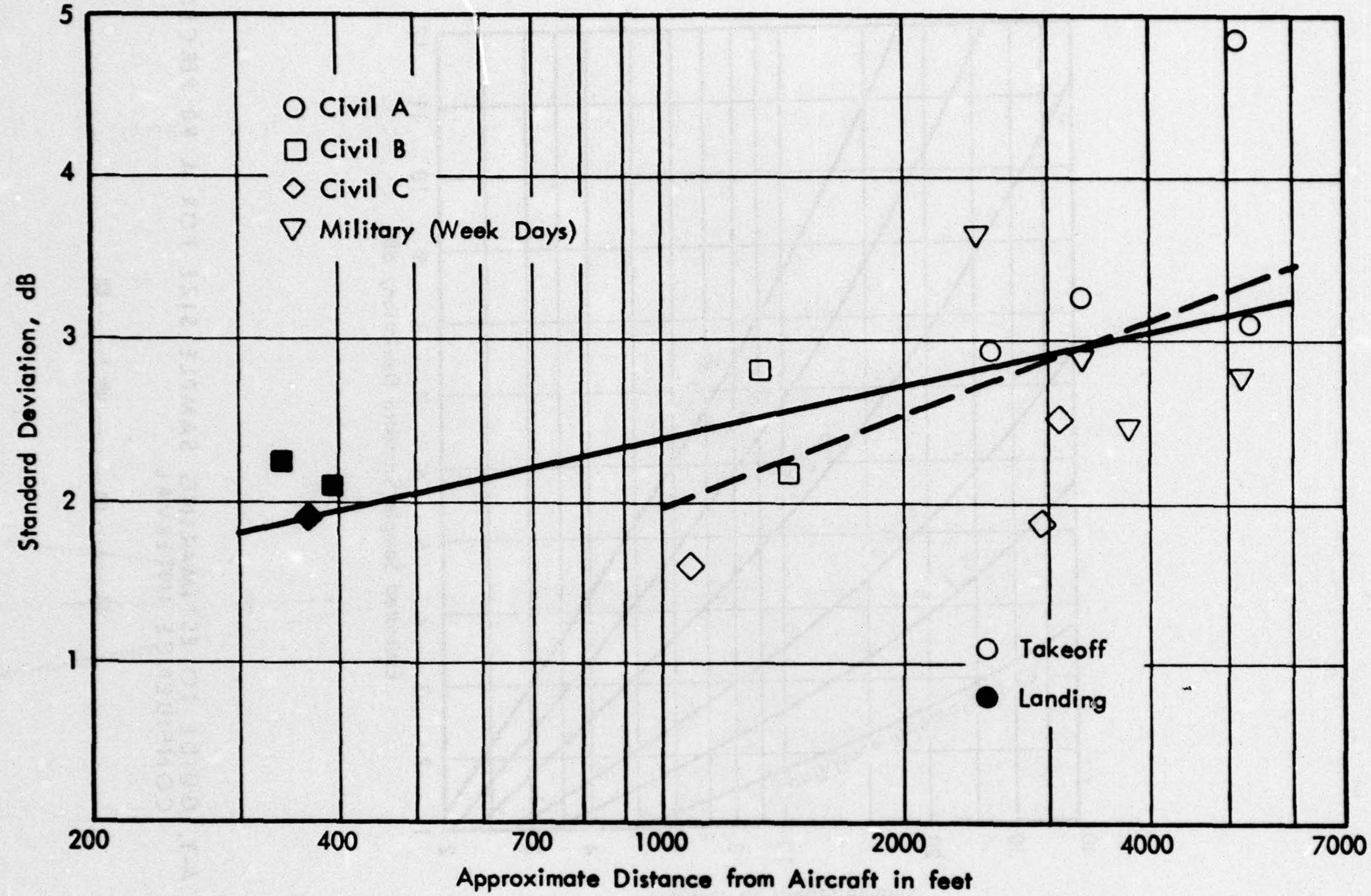

FIGURE A-2. OBSERVED VARIABILITY IN DAILY MEASUREMENTS OF LDN OR CNEL

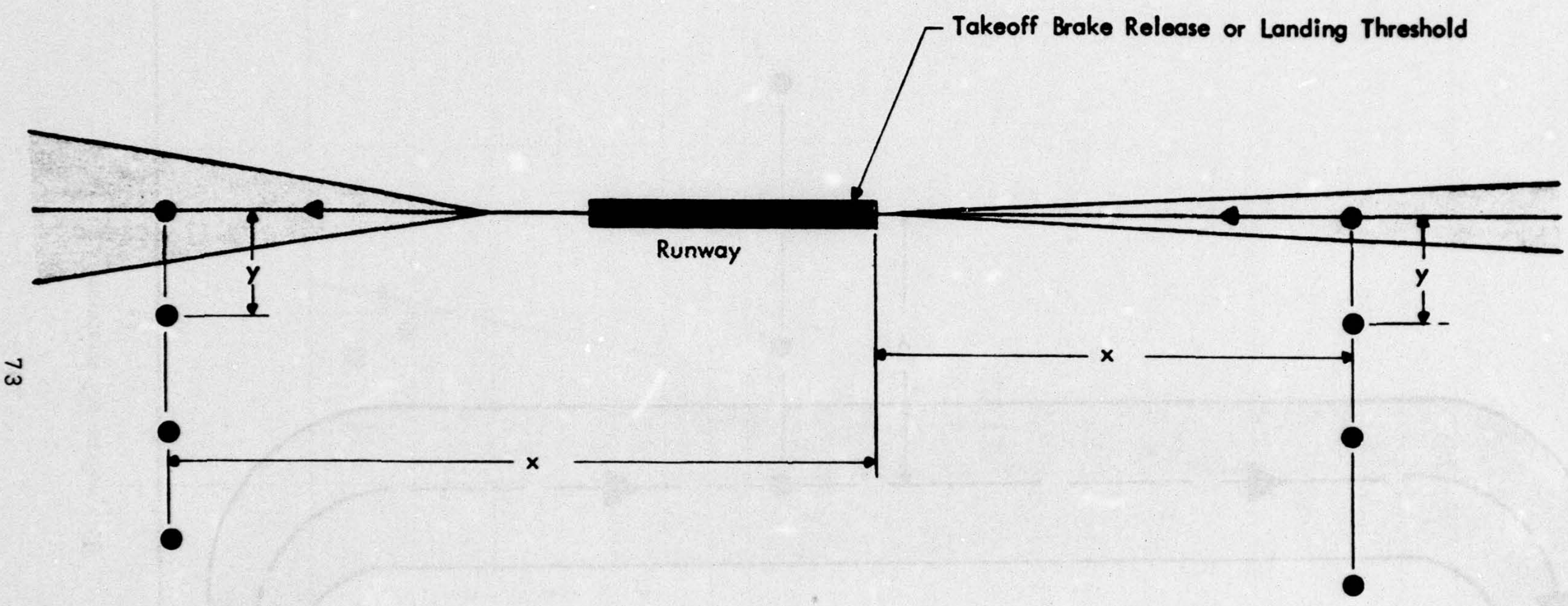

FIGURE A-3. TYPICAL NOISE MONITOR PLACEMENT FOR ARRIVAL AND DEPARTURE PATHS

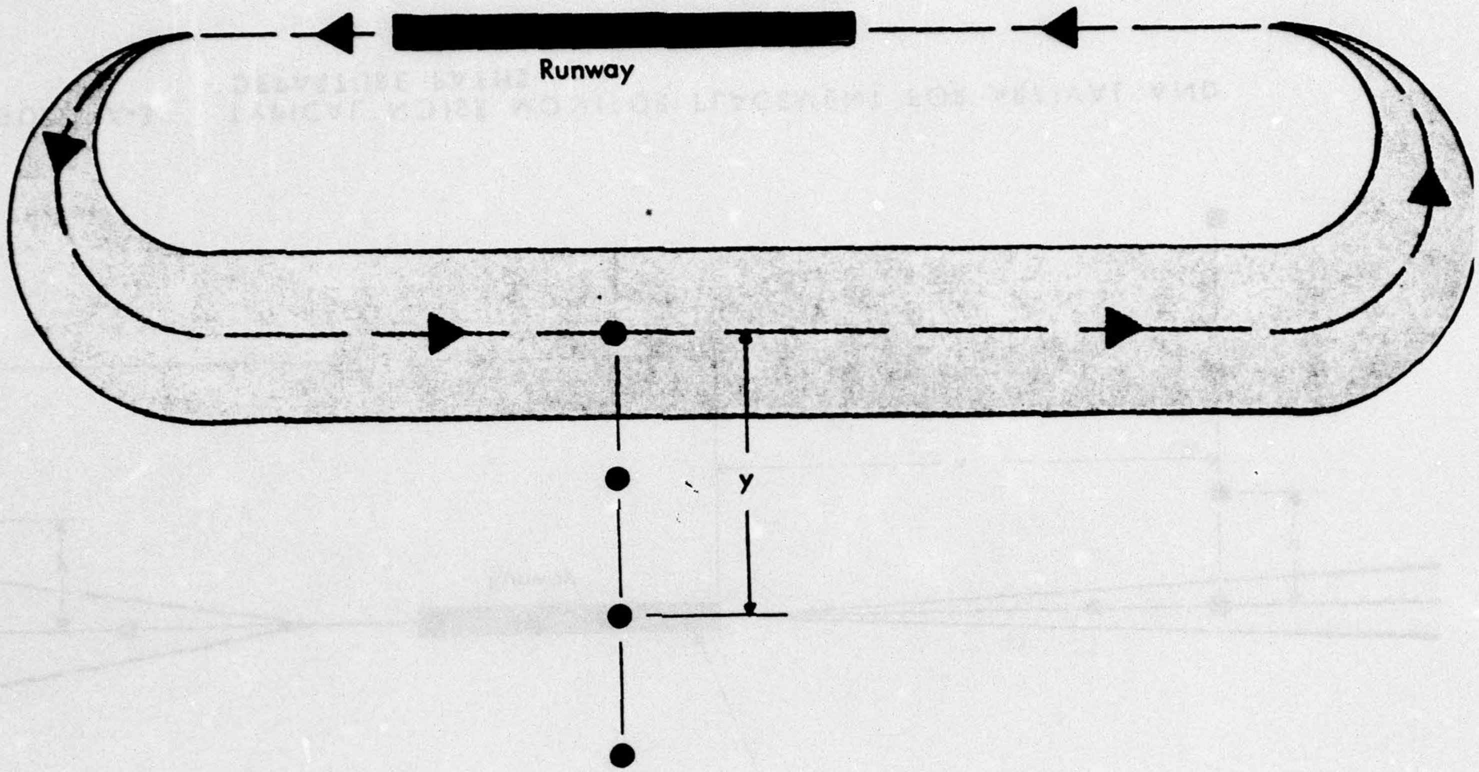

FIGURE A-4. TYPICAL NOISE MONITOR PLACEMENT FOR CLOSED LOOP PATTERN

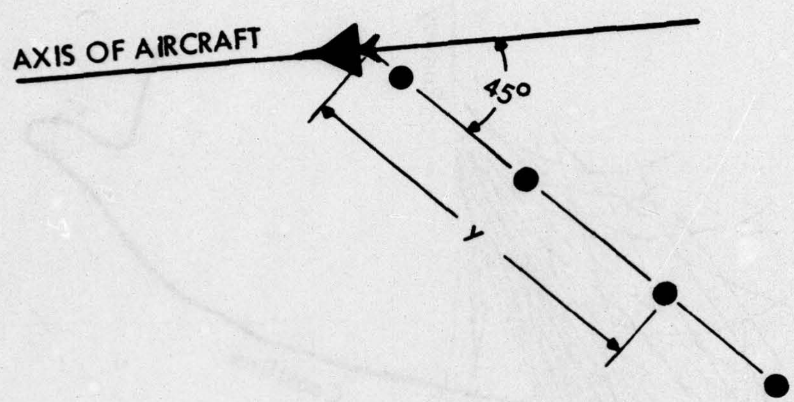

FIGURE A-5. TYPICAL NOISE MONITOR PLACEMENT FOR ENGINE GROUND RUNUPS

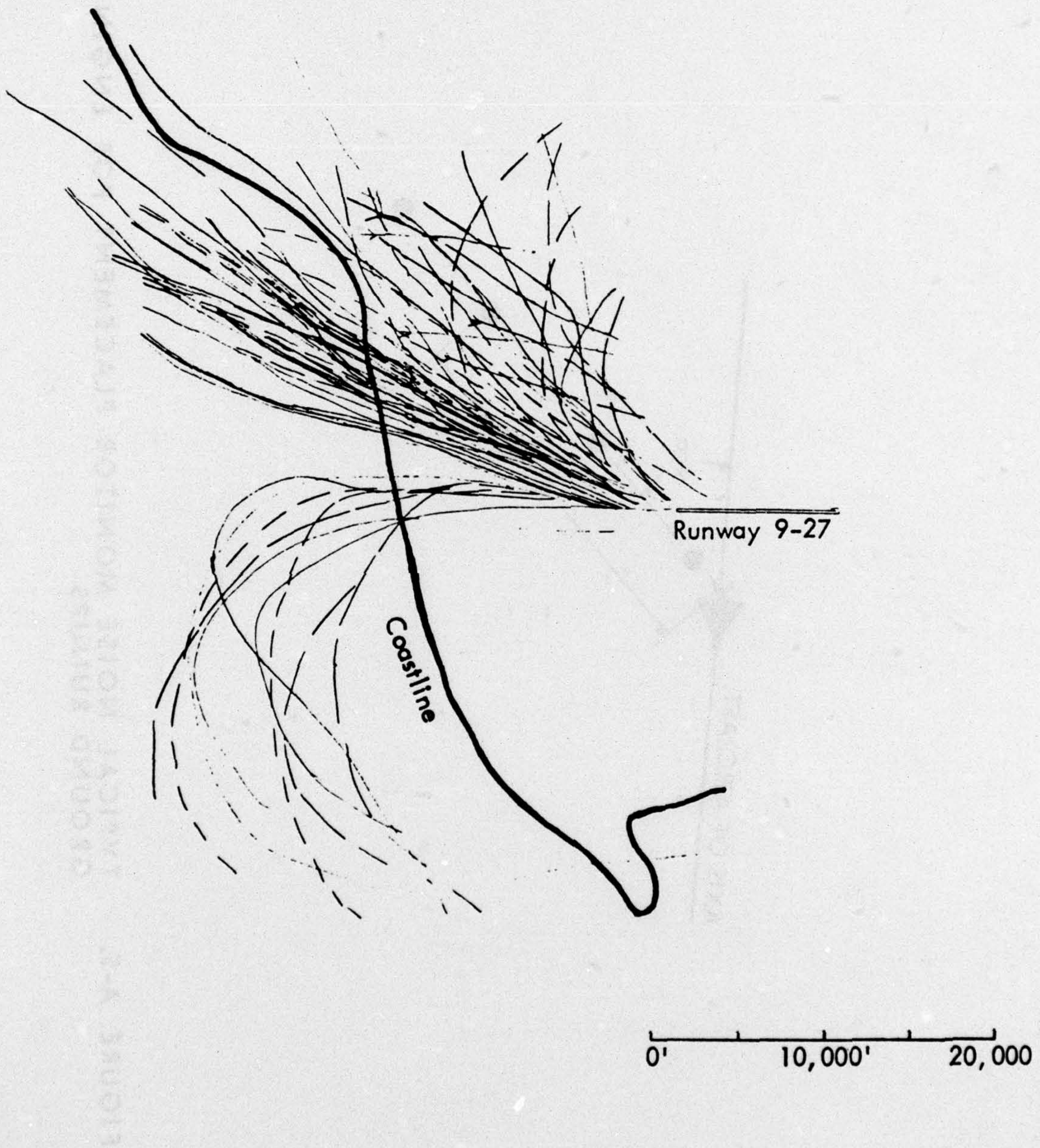

FIGURE A-6. TYPICAL RADAR SCOPE TRACINGS OF AIRCRAFT DEPARTURE PATHS

AIRCRAFT DEPARTURE ACTIVITY LOG

SITUATION: 2

INSTALLATION: Castle AFB

ROUTE: Normal St. out

RUNWAY: 30

DATE:

SHEET: of

TIME	AIRCRAFT	AFTER-BURNER (Y/N)	COURSE DEVIATION (L/R)	ALTITUDE DEVIATION (H/L)	COMMENTS

FIGURE A-7. TYPICAL DEPARTURE ACTIVITY LOG FORM

AIRCRAFT APPROACH ACTIVITY LOG

SITUATION: 1
INSTALLATION: Castle AFB
ROUTE: Normal St. in
RUNWAY: 30

DATE:
SHEET: of

TIME	AIRCRAFT	OVERHEAD (Y/N)	COURSE DEVIATION (L/R)	ALTITUDE DEVIATION (H/L)	COMMENTS

FIGURE A-8. TYPICAL APPROACH ACTIVITY LOG FORM

SUMMARY OF DAILY DEPARTURE ACTIVITY

SITUATION: 2 DATE: ____

INSTALLATION: Castle AFB

ROUTE: Normal St. out

RUNWAY: 30

AIRCRAFT	ENGINE POWER SETTING	NO. OF MOVEMENTS		
		DAYTIME (0700-2159)	NIGHTTIME (2200-0659)	TOTAL (0000-2359)
	AFTERBURNER			
	MILITARY			
	AFTERBURNER			
	MILITARY			
	AFTERBURNER			
	MILITARY			

FIGURE A-9. TYPICAL SUMMARY OF DAILY DEPARTURE ACTIVITY FORM

SUMMARY OF DAILY APPROACH ACTIVITY

SITUATION: 1 DATE: ____________

INSTALLATION: Castle AFB

ROUTE: Normal St. in

RUNWAY: 30

AIRCRAFT	TYPE APPROACH	NO. OF MOVEMENTS DAYTIME (0700-2159)	NIGHTTIME (2200-0659)	TOTAL (0000-2359)
	OVERHEAD			
	STRAIGHT IN			
	OVERHEAD			
	STRAIGHT IN			
	OVERHEAD			
	STRAIGHT IN			

FIGURE A-10. TYPICAL SUMMARY OF DAILY APPROACH ACTIVITY FORM

AIRCRAFT APPROACH ACTIVITY LOG

SITUATION: 5

INSTALLATION: March AFB

ROUTE: Radar Pattern

RUNWAY: 3/

DATE: ____________

SHEET: ____ of ____

TIME	AIRCRAFT	CHECK APPRORIATE BOX: OVERHEAD APPROACH	CHECK APPRORIATE BOX: DEPARTURE	CHECK APPRORIATE BOX: PRACTICE PATTERN	COMMENTS

FIGURE A-11. TYPICAL PRACTICE PATTERN ACTIVITY LOG FORM

GROUND RUNUP ACTIVITY LOG

SITUATION: 4 DATE: ______

INSTALLATION: March AFB SHEET: ____ of ____

TURNUP AREA: K 1

AIRCRAFT AND/OR ENGINE TYPE	TIME OF DAY		TOTAL ENGINE RUN TIME (MIN)	PERCENT OF TIME AT POWER SETTINGS			
	ON PAD	OFF PAD		A/B	MIL	RED.	IDLE

FIGURE A-12. TYPICAL GROUND RUNUP ACTIVITY LOG FORM

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